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Photometrix

User Manual for *Australis*

Australis
Software for Close-Range Digital Photogrammetry
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Quick Reference Note

For a quick reference to all program controls such as toolbar buttons, cursors, menus within the Image View and 3D View workspaces, refer to Appendix A.

Note on Camera Settings and Operation

Recall that there are three basic rules which apply to recording images for photogrammetric measurement with *Australis*:

1. The camera lens should not be refocused during the photography session.
2. If using a zoom lens, the zoom setting should not be adjusted during the photography session.
3. Where the camera has an 'auto rotate' function, which digitally rotates the recorded image, turn this feature OFF.

1. *Australis* User Interface

Upon running *Australis* (double-click on desktop icon) the user is presented with the screen shown in Figure 1.1. There are two basic windows, the scrollable 'Thumbnail Window' at the left of the screen which lists the camera(s) and image thumbnails used in the project, and a main 'Workspace' window in which image measurement and graphics operations occur. An example, which shows image thumbnails along with a graphical view of the image stations and measured 3D point locations, is shown in Figure 1.2.

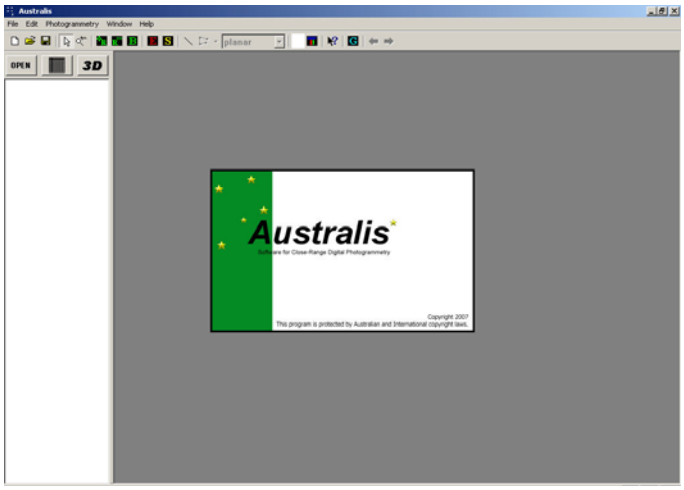


Figure 1.1

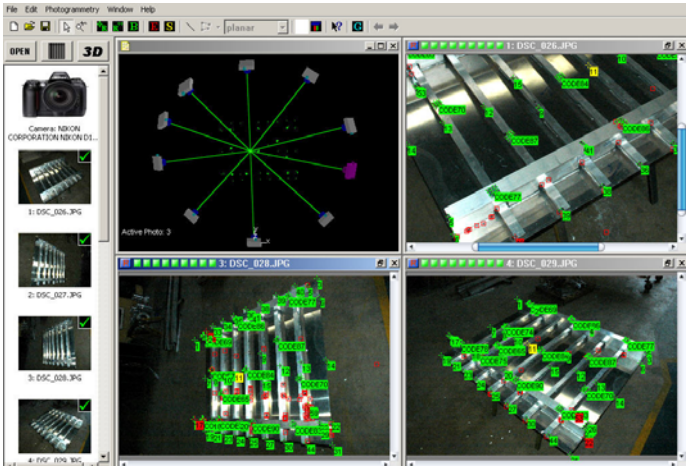


Figure 1.2

Generally speaking, *Australis* will be used to make automatic 3D measurements of an array of targetted points on an object of interest. The targets for measurement points will usually comprise retro-reflective 'dots' and coded targets will be employed to facilitate the automatic measurement. Samples of dot targets and coded targets are shown in Figure 1.3.

Shown in Figures 1.1 and 1.2 are the main menus and toolbars for *Australis*. These have deliberately been kept to a minimum to facilitate maximum ease of use. The menu options and toolbar icons will be explained later and a full description of functions is provided in Appendix A. Note that the list of *Hotkey functions* listed in Appendix A can also be accessed from the **Help** pull-down menu or the '**?**' on the toolbar.

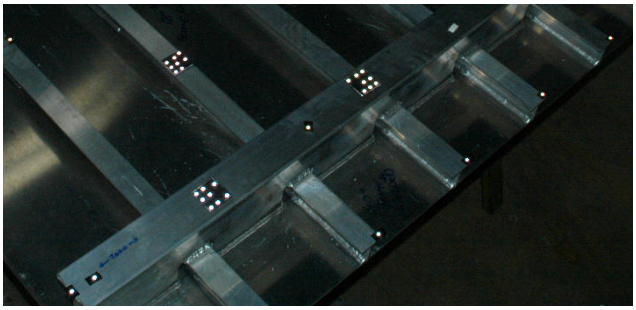


Figure 1.3

2. Project Set Up

2.1 Importing Project Images

Upon running *Australis* and commencing a new project, the operator first selects **File|New** from the main **File** pull-down menu. The first function to perform is the importing of selected images into the project. This is carried out as follows:

- If the project is new, *Australis* will enter the *Import Images* function. Alternatively, this can be selected with **File|Import Images** for an existing project.
- The user then selects from the Image Browser the folder holding the images. At this point the window shown in Figure 2.1 appears. An image in the **Select Image(s)** list is transferred into the project by first highlighting the image or images and then selecting the '>' button. The '>>' button moves all images into the project. Similarly, the '<' button moves highlighted images out of the project list, and '<<' removes all images.
- A single image at a time can be selected, or multiple images can be highlighted by either dragging the mouse over the images (as shown in Figure 2.1; left-mouse click and drag) or holding down the CTRL key while selecting multiple images. Holding down the SHIFT key means all images between the two selected images will be highlighted.
- *Australis* currently supports JPEG (*.jpg) and TIFF (*.tif) image formats.
- If the image files do not contain information which identifies the camera(s), a warning message is displayed. This indicates that before the importing of images into the project, camera data must be entered either manually, or by selecting the appropriate camera from the *Australis* camera database.

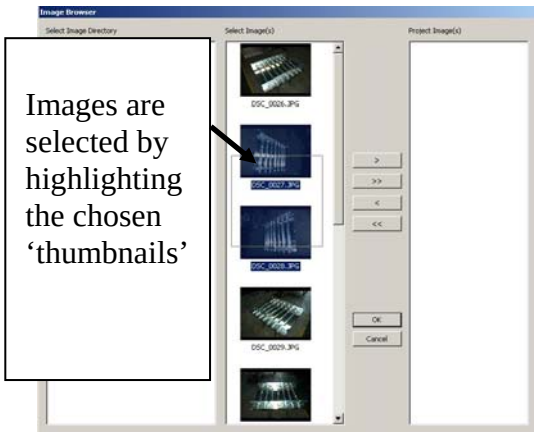


Figure 2.1

Once the images are selected, they will appear as in Figure 2.2 and to enter them into the project the user selects **OK.**

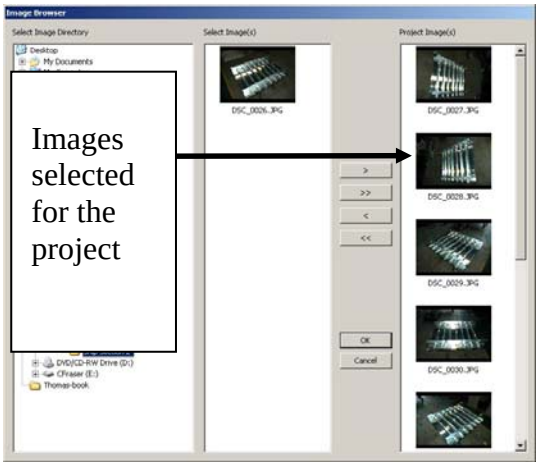


Figure 2.2

2.2 Selecting the Camera

Australis requires a camera to be assigned to the images in the project. Generally, there is only one camera per project, but there may be more than one. An up-to-date list of cameras and their key metric design characteristics is provided with the *Australis* software. The operator generally does not have to identify the camera or cameras used in the project; this is done automatically. Figure 2.3 shows a sample of the list of the camera parameters that can be displayed in the main window by double-clicking on the camera icon and then selecting **Details**. Calibration values can be changed interactively, though this is rarely required.

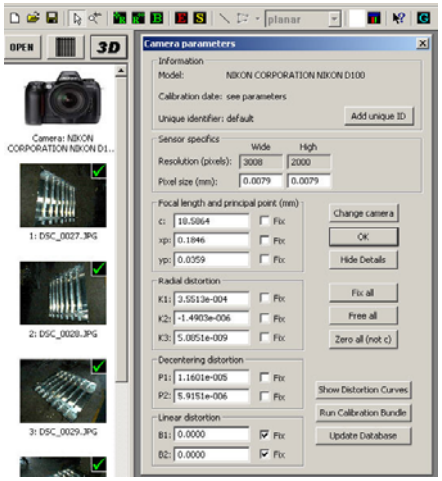


Figure 2.3

3. Automatic Measurement Operation

3.1 Procedure

The most common mode of operation of *Australis* is fully automatic 3D measurement, where a network of multiple images covering an array of object targets has been recorded with a specific geometric network of camera stations. Such an example is indicated in Figure 3.1.

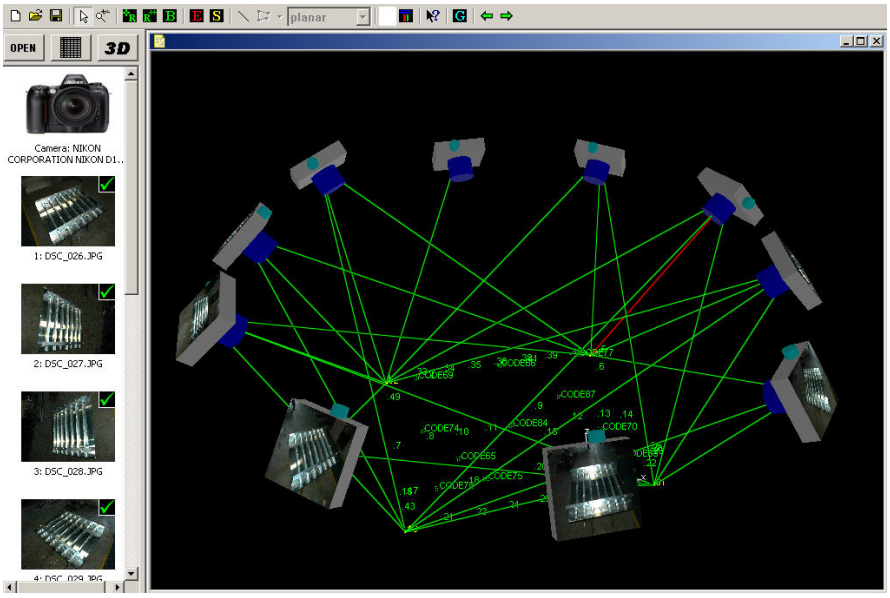


Figure 3.1

The photogrammetric network of images and object points must have the following characteristics if *Australis* is to perform a fully automatic measurement:

i) Every targetted object point must appear in two or more images that provide good ray intersection geometry (see Figure 3.1). The targets should be as distinct as shown in Figure 1.3 (ie bright against a dark background such as is achieved with retroreflective targets)

ii) There needs to be a sufficient number of coded targets, such that any five coded targets must appear on two or more images. It is not necessary that all codes are seen in all images, but codes provide the link between images so having subsets of five or more codes seen in two or more images is quite important.

iii) The network should have strong convergent geometry, as indicated in Figure 3.1.

iv) The array of images must include both 'portrait' and 'landscape' orientations. This means that the camera must be rotated or 'rolled' 90 degrees between images. It is not necessary to have exactly half with a 90 degree roll and half with no roll, but some of the images and preferably more than 30% must be rolled.

3.2 Initial Camera Self-Calibration

Automatic measurement with *Australis* requires that the camera be first calibrated, at least so approximately representative calibration parameters are available for the auto-referencing process, in which the camera calibration is further refined. This camera self-calibration step generally need only be carried out once, the first time the camera is used. The self-calibration uses the normal measurement network, Figure 3.1, with the only provision being that there are a sufficient number of coded targets in each image. Six to eight codes or more per image are recommended.

Once these requirements are met and the images are loaded into the project (stage indicated by Figure 2.2), the network of coded targets is automatically measured to provide the camera self-calibration. This is initiated by choosing **AutoCal** from the pull-down **Photogrammetry** menu as indicated in Figure 3.2.

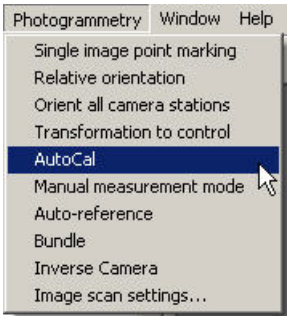


Figure 3.2

The initial self-calibration process concludes with a listing of the updated camera parameters, as shown in Figure 3.3. A further more comprehensive account of automatic camera calibration is provided in Section 9 of this Users Manual.

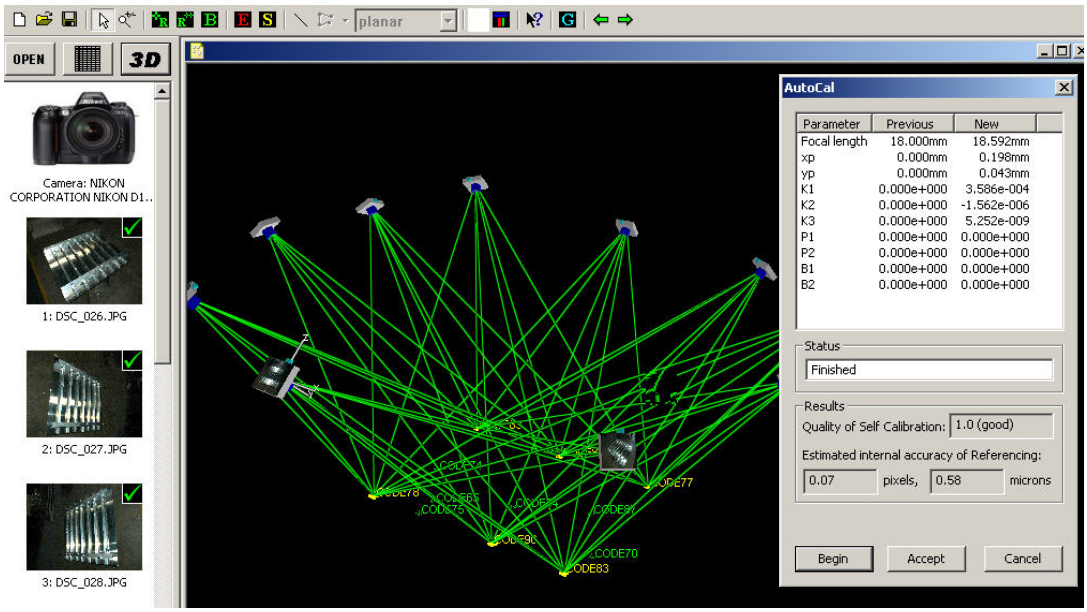


Figure 3.3

3.3 Automatic 3D Measurement

Once the initial self-calibraton has been completed (only if necessary), fully automatic 3D measurement of the object targets can be commenced by selecting **Auto-reference** from the pull-down **Photogrammetry** menu, or from the **R**$^{++}$ toolbar button, as indicated in Figure 3.4.

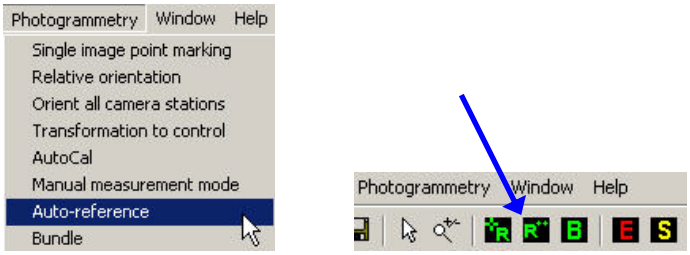


Figure 3.4

Note on image scanning: Automatic measurement requires that all image points are detected within the imagery in an initial image scanning process. This requires high contrast between target blobs and background as well as particular characteristics for the image points. There is

generally no need to adjust image scanning parameters, but this option is available, as is fully described in Chapter 16.

The operator then selects **Begin**, as shown in Figure 3.5. Once the operation is complete, as indicated by the *Auto Referencing Finished* message and the screen plot of the network, the operator selects **Close** after reviewing the results summary.

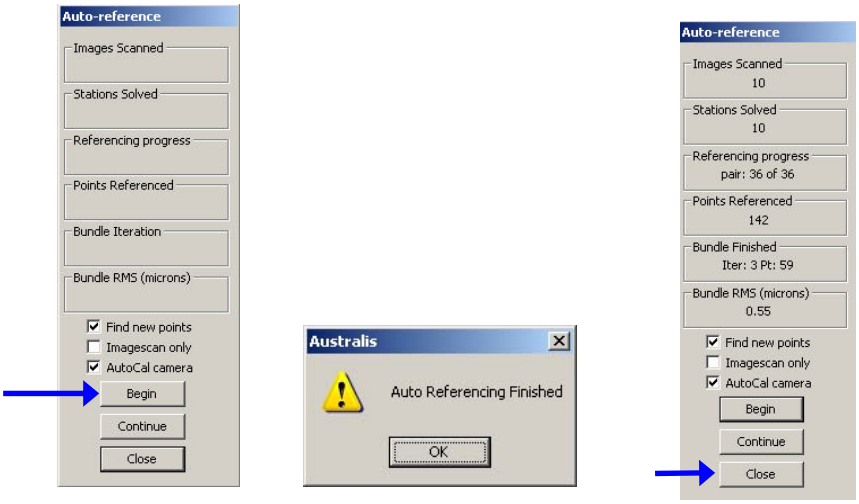


Figure 3.5

The basic 3D photogrammetric network is now measured, which means that its shape is determined, but not its size or alignment with a chosen XYZ coordinate system. The operator can assess the results of the measurement by referring to the coordinate listing, which is provided by selecting the 'List' button next to the **OPEN** button in Figure 3.3.

The project should be saved at this point, via the normal **File|Save** function. The project file, which can be reopened at any time is called ***projectname*.aus**.

Note that by right-clicking in the 3D View a list of options is presented so the operator can do such things as show and hide labels, show and hide axes, etc. This list is shown in Figure 3.6. There are also hotkeys for these functions, which are listed both below in Figure 3.7 and in Appendix A. These are accessed via the **Help** toolbar button and the '**?**' button.

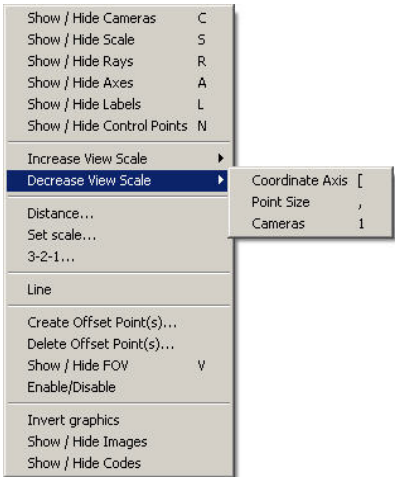


Figure 3.6

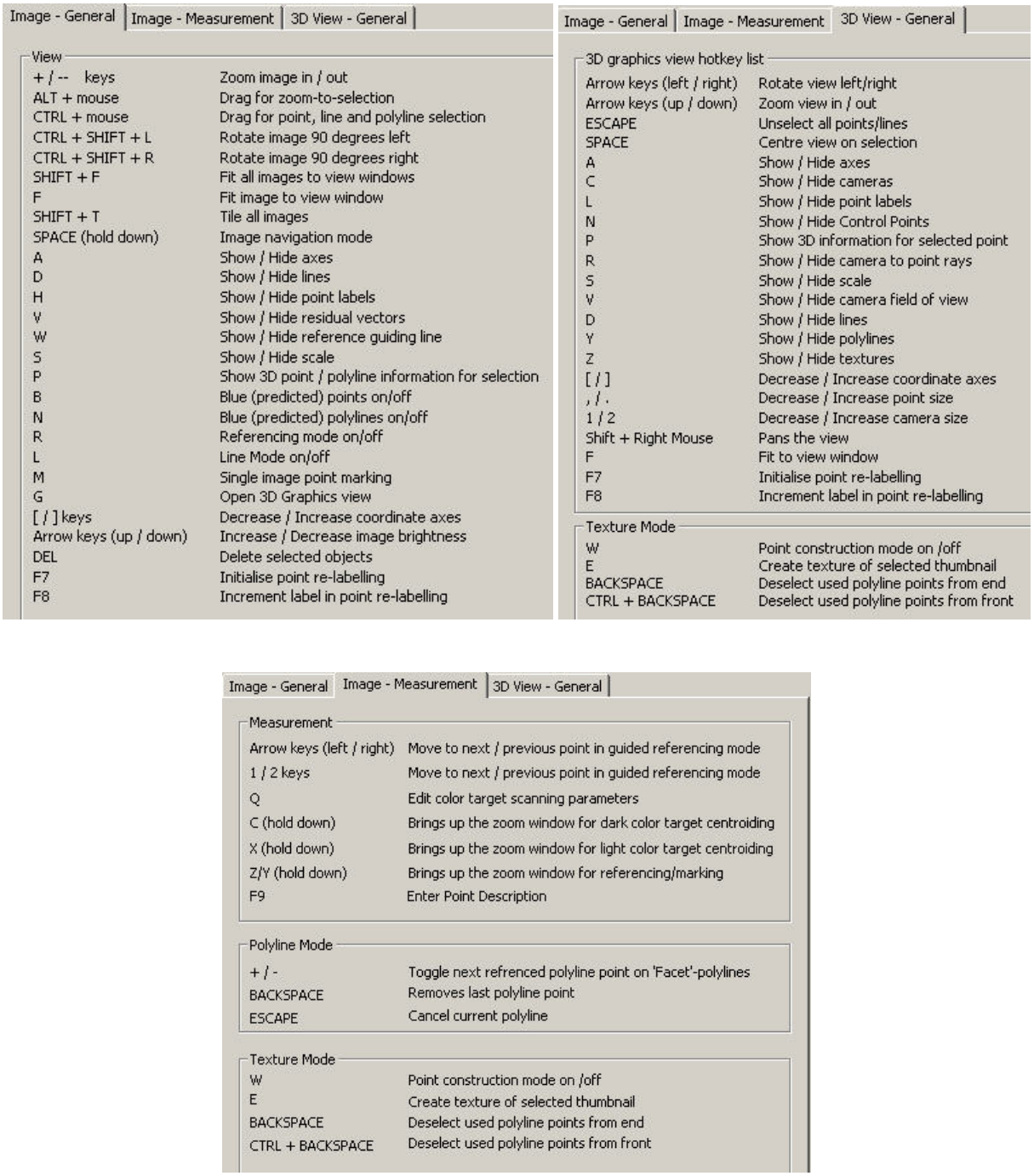


Figure 3.7

3.4 Bundle Adjustment

The final stage of the automatic measurement process within *Australis* is the bundle adjustment, a least-squares estimation process that computes the photogrammetric network orientation and thus the XYZ coordinates of all object feature points. There are a number of circumstances that will lead the user to require a recomputation of the bundle adjustment at the end of an automeasure sequence. This is initiated via the **B** toolbar button or the **Photogrammetry**|**Bundle** menu selection, the associated dialog being as shown in Figure 3.8.

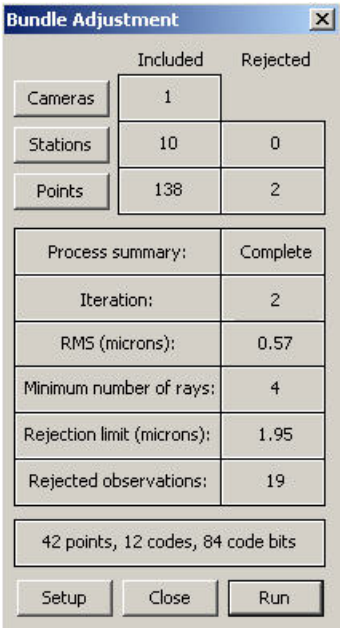


Figure 3.8

Upon selecting **Run**, the user will be presented with the statistics of the bundle adjustment solution, namely the number of cameras employed, the number of image stations accepted and rejected, the number of object points accepted and rejected. A number of important metrics are also provided; these include the number of iterations involved, the image coordinate misclosure value (*RMS (microns)*), the assigned minimum number of rays per point, the observation rejection limit and the number of rejected image coordinate observations. The numbers of single points, coded targets and code 'nuggets' are also listed.

It is often desired to re-run the bundle adjustment with altered tolerance values, the two most common being the *Minimum number of rays* per point and the *Rejection limit*. The **Setup** button is used to assign the new values, the dialog being shown in Figure 3.9.

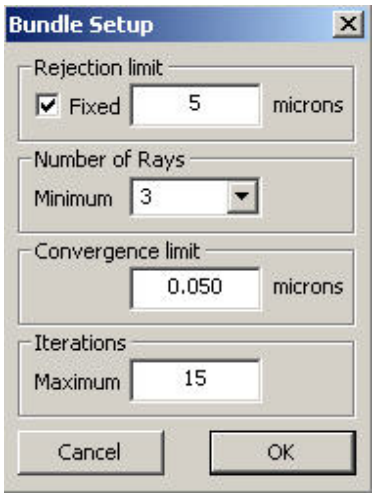


Figure 3.9

A ‘fixed’ rejection limit (in micrometres) for image coordinate residuals can be set by ticking *Fixed* and then entering the desired value, 5 microns in this case, which is much looser than the automatically set value of 1.95 shown in Figure 3.8. The *minimum number of rays* has also been changed to 3 in Figure 3.8, which means that a 3D point will be accepted if it is triangulated by three non-rejected rays. It is very rarely the case that either the *maximum number of iterations* or the *convergent limit* would need to be changed from their default values.

Shown in Figure 3.10 is the summary dialog for the re-run bundle adjustment with the altered tolerance values displayed in Figure 3.9. The relaxing of the rejection limit, coupled with changing the minimum number of rays to 3, has resulted in two previously rejected points now being accepted, but the adjustment quality is slightly poorer, the RMS value of image coordinate residuals rising from 0.57 to 0.64 micrometres.

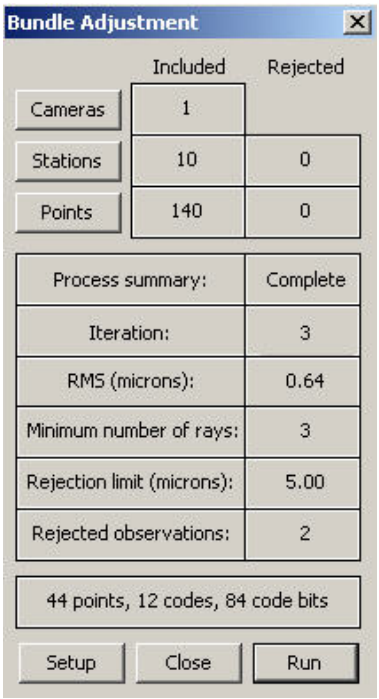


Figure 3.10

3.5 Coordinate List and Point Dialog

The *3D List* of currently measured XYZ coordinates is obtained by clicking on the button, as indicated in Figure 3.11. The list shows the point labels (numbers or alphanumeric labels), coordinates, number of images upon which the point appears, the RMS misclosure of triangulation (a quality indicator, expressed in micrometres) and the maximum angle of intersection between intersecting rays to a point. The overall RMS misclosure value is also shown, as are the number of points and codes in the network.

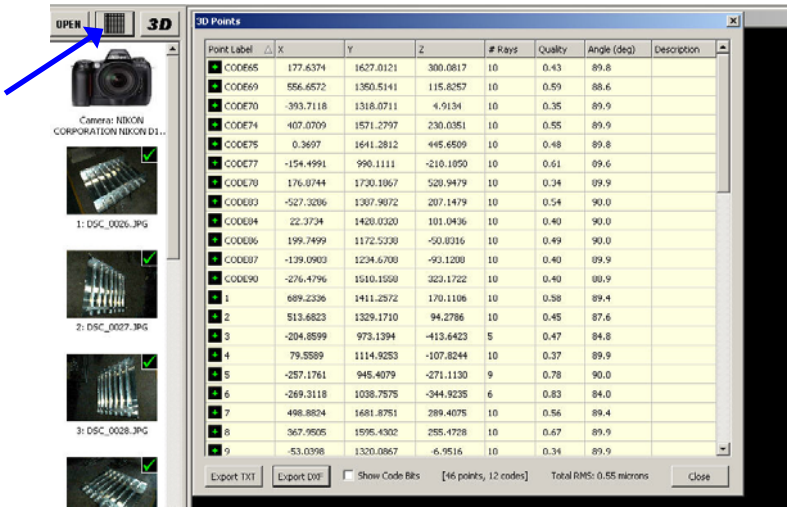


Figure 3.11

A *Point Dialog Box*, shown in Figure 3.12, can be selected by double-clicking on the point label. This shows the current point label, quality factor (RMS misclosure value in pixels), and a list of the individual image measurement residuals for each image seeing the point. Also shown with the XYZ coordinates are the corresponding standard errors (SX, SY, SZ). A red cross, instead of green, indicates that the image point observation has been rejected.

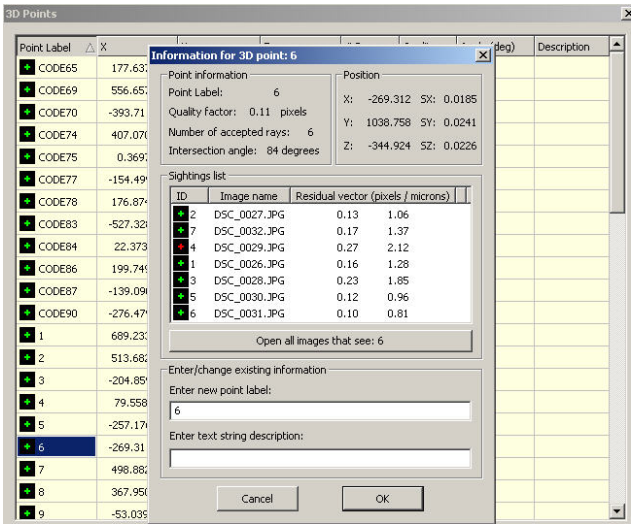


Figure 3.12

3.6 Point Re-labelling

To re-label a point, simply type the desired label into the *enter new point label* box of the Point Dialog shown in Figure 3.12. The new label will now appear in the Image and 3D Views. A description can also be entered and this will be written to the DXF file on coordinate output.

As an alternative, it is possible to manually relabel strings of points with sequentially increasing numbers. This is more convenient when there is a lot of point relabelling required. The steps are as follows:

1) Assume that it is desired change the labels of the points below in Figure 3.13 as follows: 27 to Edge_31, and then 25, 24, 23 and 21 to Edge_32 to Edge_35. Also, label 19 is to be changed to Corner10. The changes can now be made in either the Image or 3D Views.

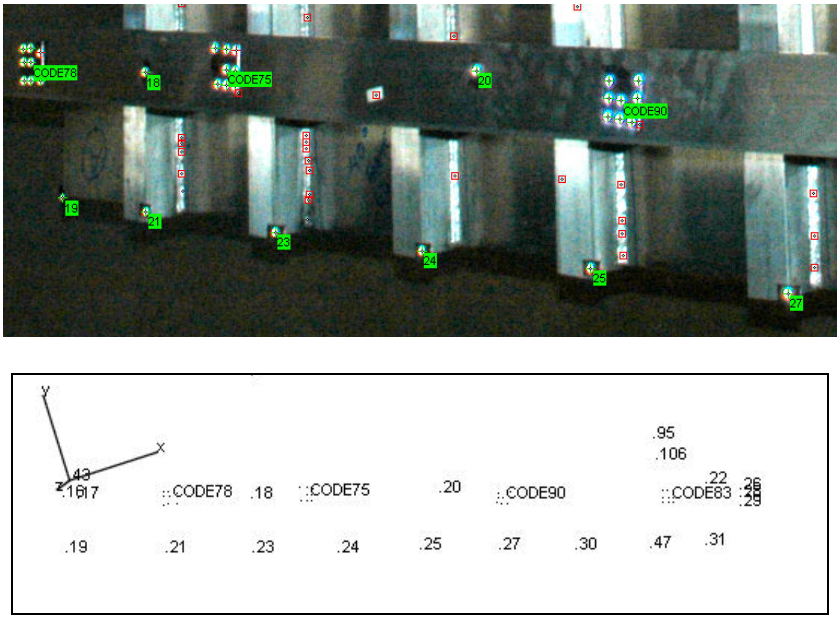


Figure 3.13

2) Select point 21 & then hit the **F7 key**. The following dialog, Figure 3.14, will appear

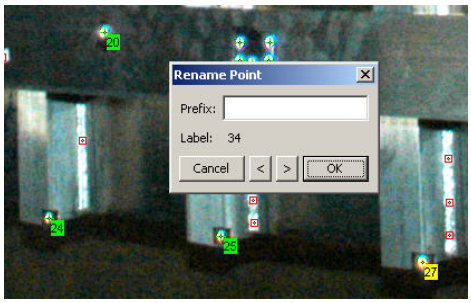


Figure 3.14

3) Enter the prefix ‘Edge_’ and use the arrow keys to select the start number, in this case 31, as indicated in Figure 3.15.

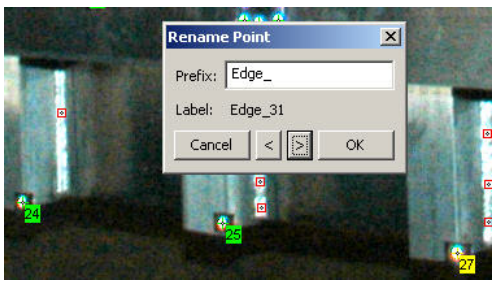


Figure 3.15

Select **OK** and the point label will change to the desired new label, as in Figure 3.16.

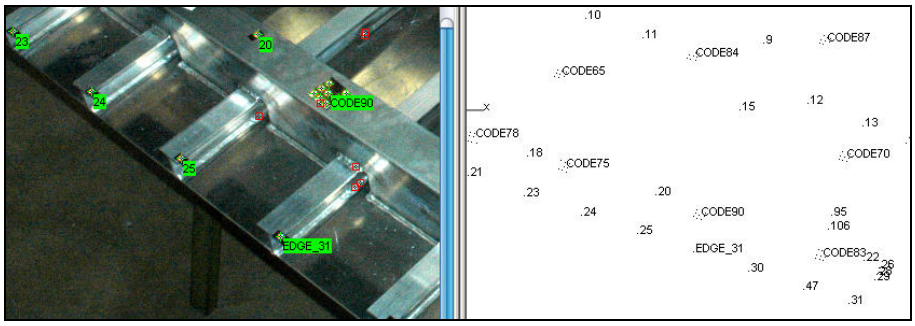


Figure 3.16

4) Note that it is not necessary to first highlight a point before calling up the label dialog via the **F7** key. Instead, **F7** can be selected and the new label inserted before any points are highlighted. After closing the dialog with OK, simply highlight the point and hit the **F8** key and it will assume the new label.

5) Following the relabelling of a point via the **F7** option, additional points that are to be assigned the same label prefix (eg Edge_) can be relabelled. The operator need only highlight the point and hit **F8**. The label number will then automatically increment by 1. So, you select 25 & hit **F8**, select 24 & hit **F8**, select 23 & hit **F8** and finally select 21 & hit **F8** and the labels will appear as in Figure 3.17.

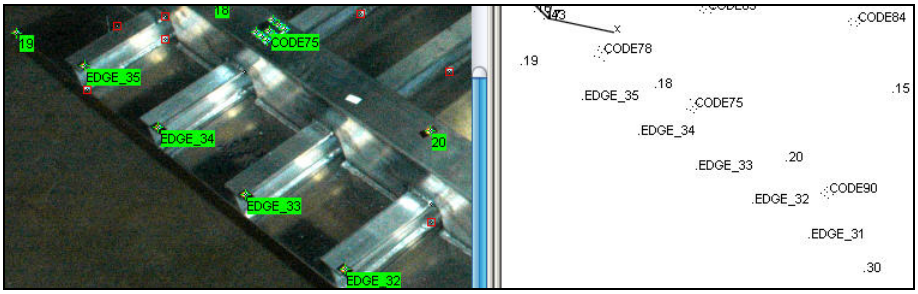


Figure 3.17

To rename 19 to Corner10, highlight 19, select **F7** and input the label as per Figure 3.18. Then, Select OK & the point will be relabelled.

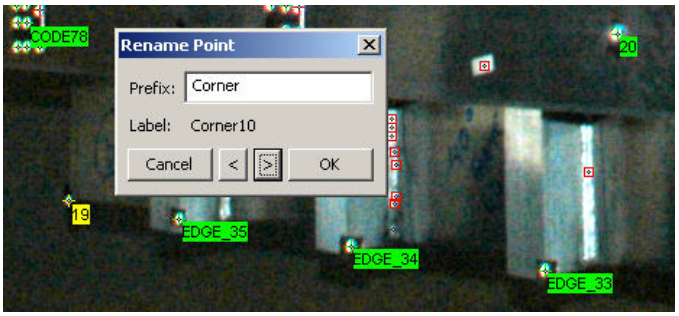


Figure 3.18

As will be described in Chapter 6, it is also possible to automatically re-label entire object point arrays using **Network Re-Labelling**. This is very useful in applications where photogrammetric surveys are repeated, as for example in deformation measurement.

The next two steps in the *Australis* data processing sequence are to scale the object to true scale and assign a particular Cartesian coordinate reference system to the object points.

4. Setting the Scale

There are three means to set object space scale, first via coded targets, second using a *Scale Database* of stored scale bar values, and third by simply assigning distances between point pairs in the object point array.

4.1 Automatic Scaling via Coded Targets

Since *Australis* uses coded targets of known sizes, it is possible to assign object space scale based on point-to-point distances between points forming the codes. To achieve this initial scaling, the user ticks **Scale via codes** from the **Edit|Project Settings menu** and ensures that the correct coded target size is also ticked (there are three standard size options). The dialog appears as in Figure 4.1. Selection of this option causes red scaled distances to be shown for coded targets within the *3D View*, as shown in Figure 4.2.

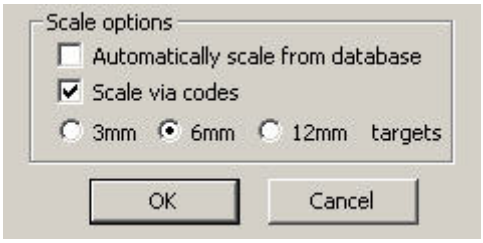


Figure 4.1

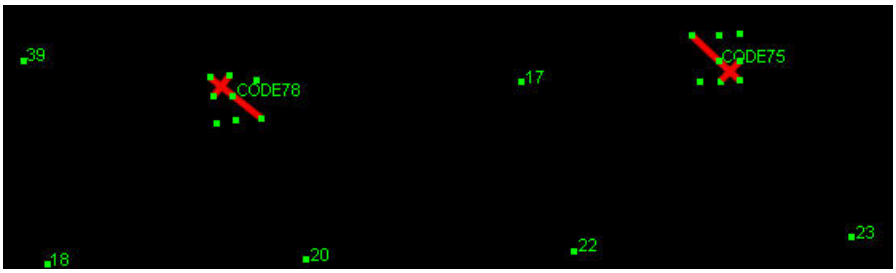


Figure 4.2

<u>Cautionary Note</u>:

The distances used to scale the network via coded targets are very short and thus small uncertainties in the mean scale will be magnified for larger point-to-point distances in the network. It is therefore recommended that scaling via codes be used where a preliminary scale of only moderate accuracy is required. Higher accuracy scaling requires one of the following two approaches.

4.2 Scaling with Known Distances

To set a true scale to the XYZ coordinates, the operator must specify one or more point-to-point distances. The scaling process proceeds as follows:

i) First, with the cursor in the 3D View, select the **L** key to show the point labels. Then, right-click in the 3D viewer window and select **Set Scale**, as indicated in Figure 4.3.

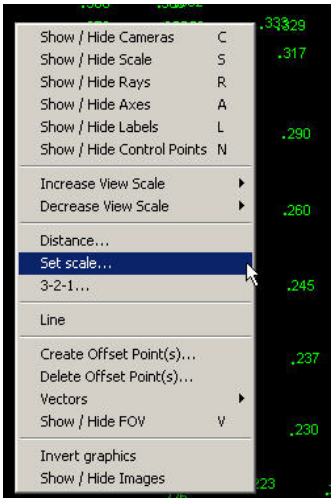


Figure 4.3

ii) When **Set Scale** is first selected (and only on the first occasion), the user is asked to specify the project units. All coordinate and distance information, such as distances input to define scale are assumed to be in these units. Note that the choice of units does not relate to camera calibration parameters; the chosen units refer only to object XYZ coordinates. The units are defined by choosing one of the four options in Figure 4.4.

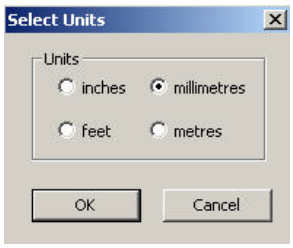


Figure 4.4

iii) The dialog box shown in Figure 4.5 then appears. The operator selects the two points A and B (from the number list) forming the known distance, and this distance is entered.

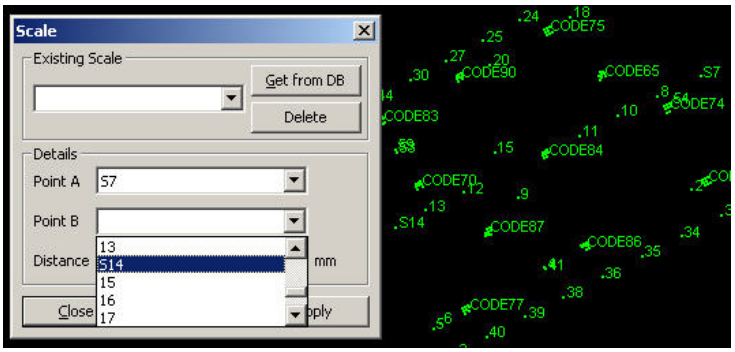


Figure 4.5

iv) To register the scaled distance, click **Apply**. At this point, or later, you can add additional distances for scale control, or even change or delete previously entered distances. Once all data is entered, press **Close**. Red lines will be drawn between the pairs of nominated 'scale points' in the Image and 3D Views. The final scale will be a weighted average of the nominated scaled distances. Figure 4.6 indicates a scale distance in the 3D View. The **S** key can be used to toggle the red line between show and hide in both the 3D and individual Image Views.

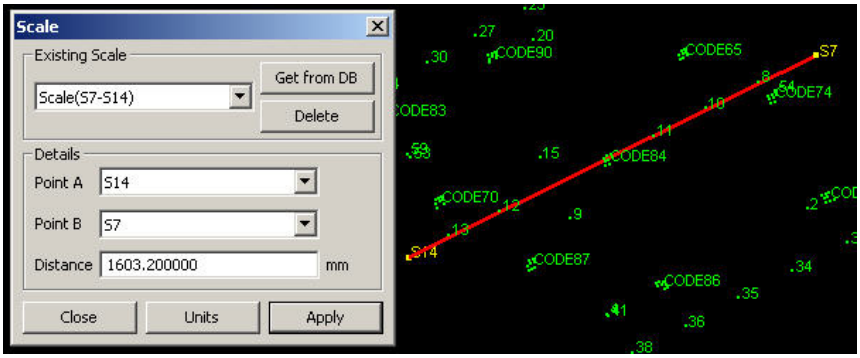


Figure 4.6

v) As an alternative to entering the numbers for points A and B, as in (iv), first highlight/select two points. Left-click in either the 3D View or Image View (with the Select tool) and then CTRL/left-click for the second point. Then, select **Set Scale**. The two selected points will be shown as Points A and B and the operator need only enter the distance and press **Apply** followed by **Close**. This is shown in Figure 4.7.

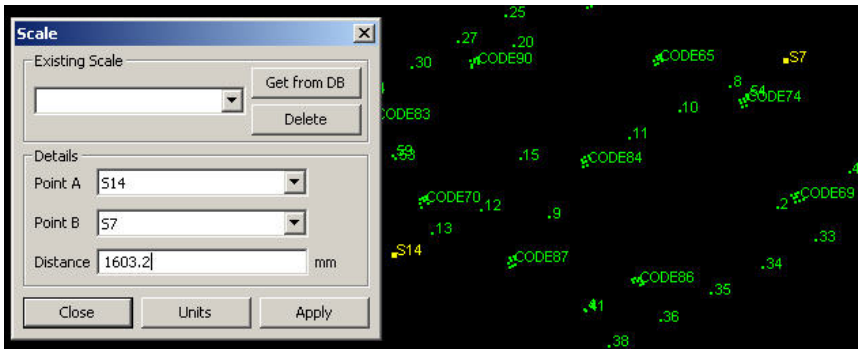


Figure 4.7

In order to check point-to-point distances after scaling, simply highlight the two end points of a line in the 3D view, right-click and then select **Distance** from the menu.

<u>Cautionary Notes</u>:

a) In the event of a drastic rescaling of the network, the 3D view may look too small or large and may require rescaling via either the mouse wheel or the **Increase** or **Decrease view scale** options (see Figure 3.6). The camera size may also need rescaling (the '1' and '2' keys).

b) Unless Set Scale is employed to fix one or more point-to-point distances, the object coordinates will be at an arbitrary scale (ie objects will not be at true size). A warning is given in this case to set scale if coordinates are to be exported via DXF or a text file, or if the project is closed without first establishing a scale.

4.3 Entering Scalebar Lengths into the Scale Database

Australis maintains a *Scalebar Database* of known distances. In order to automatically assign distances from the database to the network, it is first necessary to tick the option shown below in Figure 4.8, which is accessed from the **Edit|Project Settings menu.**

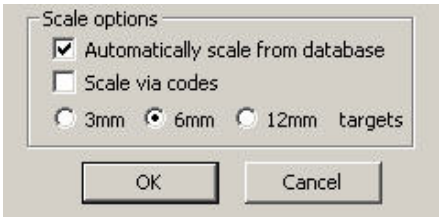


Figure 4.8

Users who employ a scalebar on many projects need only enter the distance information once. This data entry procedure is as follows:

i) Select **Edit/Scale database …** , as shown in Figure 4.9a. This will bring up the Scale dialog shown in Figure 4.9b. The next step is to enter the scalebar name, endpoint labels, length and standard error (enter 0.001 if unsure).

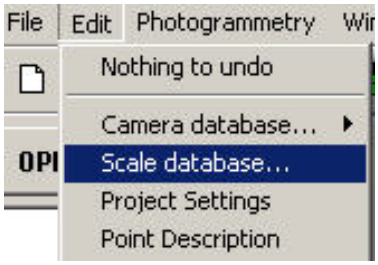


Figure 4.9a

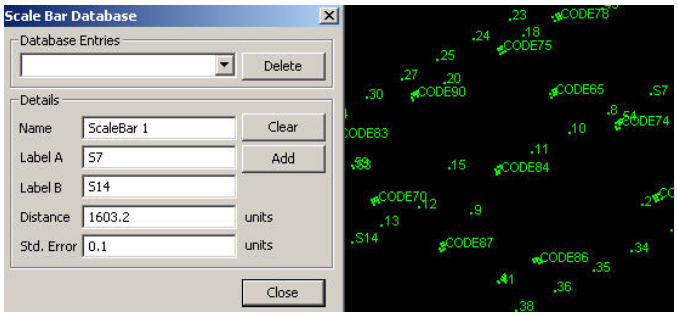


Figure 4.9b

ii) To store the scalebar information in the database, select **Add**. The input of such scalebar information can be performed at any time.

iii) To apply a scalebar distance from the scale database, first select **Set Scale** by right-clicking in the Image or 3D view. Then, select **Get from DB** and a dialog will appear from which the particular scalebar name can be selected, as indicated in Figure 4.10. Then, select **OK** and the scale information will be displayed as shown in Figure 4.11. Select **Close** to apply the scaling.

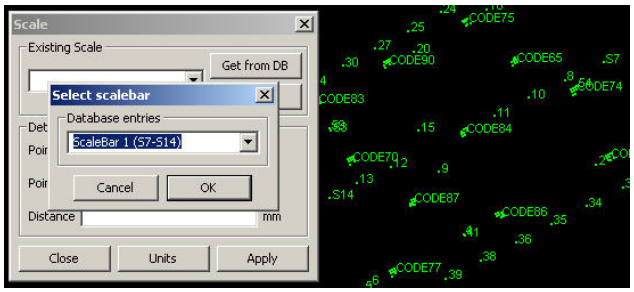


Figure 4.10

iv) To remove a scalebar entry from the database, simply select the **Delete** button in the dialog shown in Figure 4.11.

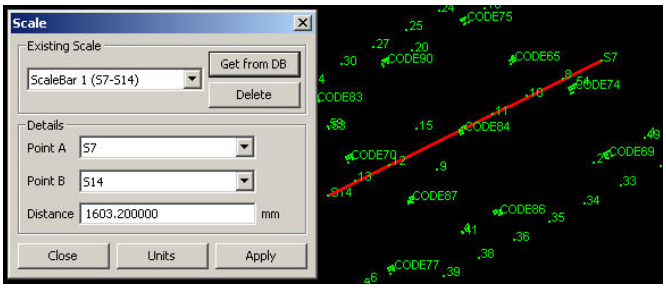


Figure 4.11

5. Assigning the XYZ Coordinate System

The process of photogrammetric orientation can be carried out within an arbitrary XYZ Cartesian coordinate system. In *Australis*, this coordinate system has its origin at the first of the relatively oriented images, and its XY plane is aligned with the focal plane of the camera at that station. In most cases the user will wish to assign a more useful XYZ reference system. This assignment of the coordinate system origin and orientation is carried out via the so-called 3-2-1 process. First, a point is selected to define the origin (X,Y,Z values of zero). Next, a point through which the X axis will pass is defined, and finally a third point is selected to define the XY plane and therefore the direction of the Z coordinate axis.

This process can be carried out either automatically via coded targets, or manually by selecting appropriate object points an then choosing the 3-2-1 command. These two XYZ datum assignment options will now be described.

5.1 Automatic Assignment of XYZ Axes

Open the **Edit|Project Settings Dialog** and enter the desired labels for the origin point, X-axis point and the point to define the XY plane orientation, as indicated in Figure 5.1. This choice of XYZ coordinate system can be made at any time, but it will only come into effect with the running of a bundle adjustment. Thus, select the **B** toolbar button if necessary. The resulting coordinate axes are displayed in the 3D View, as shown in Figure 5.1.

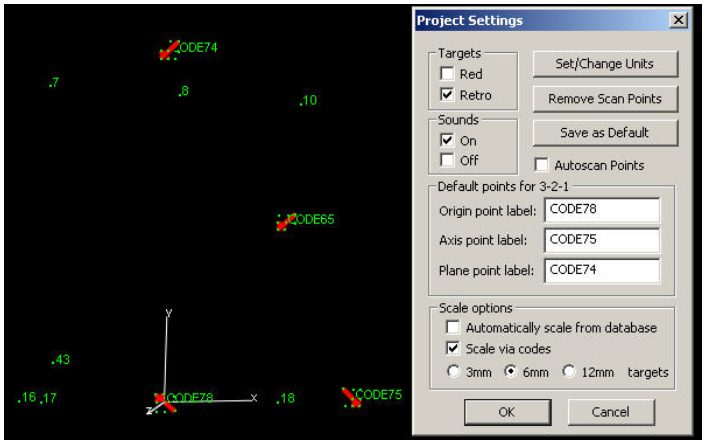


Figure 5.1

5.2 Operator Controlled 3-2-1 Process

In order to manually set the XYZ coordinate system in *Australis*, these steps are followed:

i) Select (highlight) three points in either an image view or the 3D view, in the order: origin point, X-axis point and XY-plane point, then right-click and select **3-2-1**.

ii) A dialog box then appears, as in Figure 5.2. It shows the three points and the default axes, as well as the newly assigned axes.

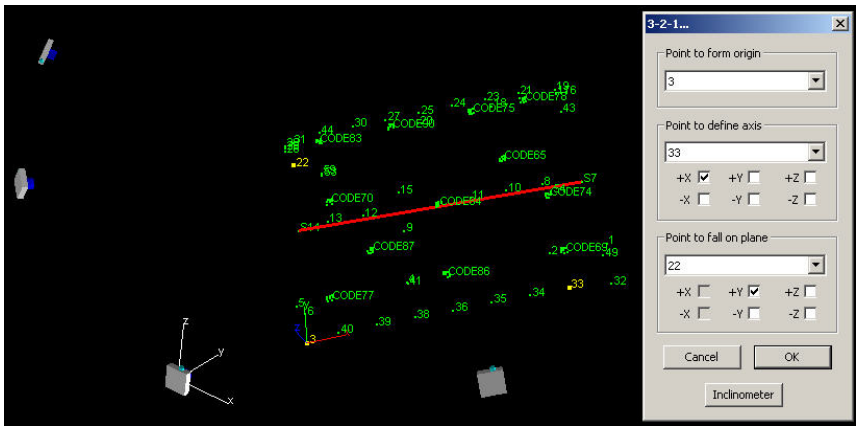


Figure 5.2

Note: The three points for the 3-2-1 process can also be selected (highlighted) in an image window, but the 3D view is necessary for viewing the newly assigned axes. The 3-2-1 process can also be selected without highlighting points, in which case point numbers are entered via the dialog box.

iii) By interactively checking the selected +X, -X, ... , -Z boxes, the axes can be swapped, keeping the right-handed Cartesian nature of the coordinate system. Once the desired axial directions are established, press the **OK** button. At this point the 3D coordinates of all points and camera stations are transformed to the new system, as shown by the point table listing in Figure 5.3.

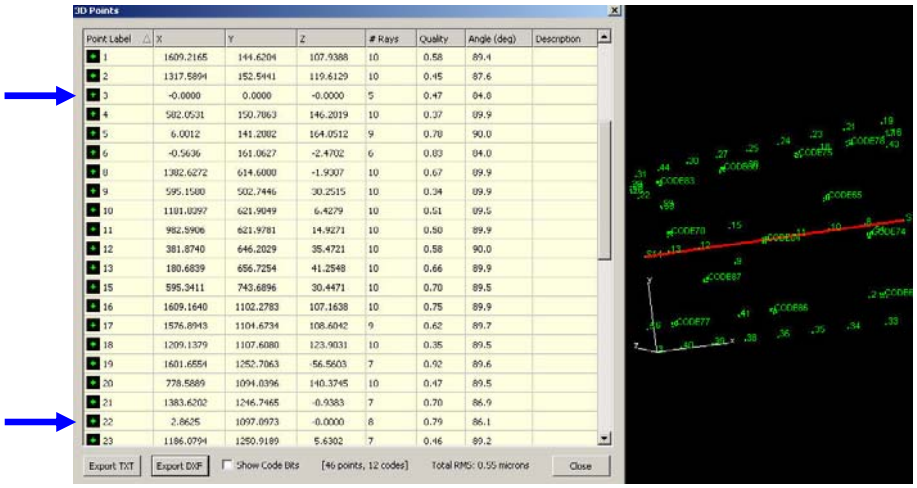


Figure 5.3

6. Transforming to a Coordinate System via Control Points

6.1 Coordinate Transformation

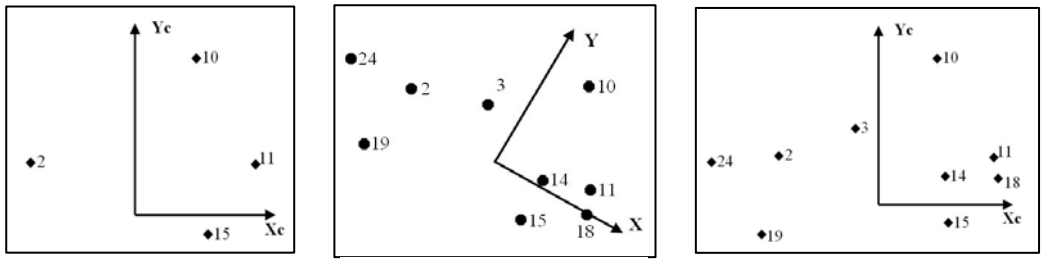
There are many situations where it is desired to tie the photogrammetrically measured 3D point coordinates into an existing coordinate system, which is defined by 'control points'. Control points have known coordinates in two Cartesian reference systems: they have X_c, Y_c, Z_c coordinates from the existing Primary or 'control' coordinate system, as well as X, Y, Z coordinates from the specified Secondary or *Australis* 3D reference system.

In such instances, it is usually desired to transform all Secondary coordinates into the Primary or control point system. *Australis* accommodates three coordinate transformation options, a block shift, 2D transformation within the XY plane, and a full shape-preserving 3D similarity transformation. The 3D transformation will be of most use to *Australis* users and so it will be explained in more detail here.

3D transformation: Given three or more control points that are non co-linear, a 3D transformation can be performed from the specified Secondary XYZ system to the Primary $X_cY_cZ_c$ system of the control points. The transformation involves a translation, three rotations and possibly a uniform scale change. This represents the general transformation case, and 2D transformations and block shifts are special cases of this general case. Figure 6.1 illustrates a 2D coordinate transformation. Basically, the provision of control points allows transformation into any chosen object space Cartesian ($X_cY_cZ_c$) reference system.

6.2 What is Needed for Coordinate Transformation?

In order to transform *Australis* XYZ coordinates into another reference coordinate system, control points are required (either a text file of control point coordinates or interactively input coordinate values). A sample control points file is shown in Figure 6.2.



a) Control points in Primary Xc,Yc system

b) Measured points in Secondary X,Y System

c) Measured points transformed into the Primary Xc,Yc system

Figure 6.1: 2D transformation of XY coordinates (Secondary system) into Xc,Yc coordinates (Primary system) via four control points (Points 2, 10, 11 and 15).

Control Points File. The format for each point record in the file must be: Control Point label, X_c, Y_c, Z_c. Not all points need also be measured in the *Australis* project, though clearly the minimum number of common point is three non co-linear points for a 3D transformation. If more points are used a least-squares estimation process is adopted to obtain a best-fit solution. Also, the point labels of the control points file and the *Australis* points do not need to correspond exactly.

Interactive Entry of Control Points for Coordinate Transformation. It is also possible to enter the control points interactively, directly into the listing within the dialog box shown in Figure 6.3. Select the **New Point** button. Each time this button is selected a new control point record will appear, with XYZ coordinate values of N/A and with a label of NEWPOINT*i*, where *i* is incremented. This dialog will be further explained in the next section.

	X	Y	Z
C-15	595.3	743.6	30.4
C-21	1383.6	1246.7	-0.9
C-33	1381.2	0.0	-0.0
C-40	178.9	5.1	41.2
C-44	184.5	1253.0	43.5

Figure 6.2

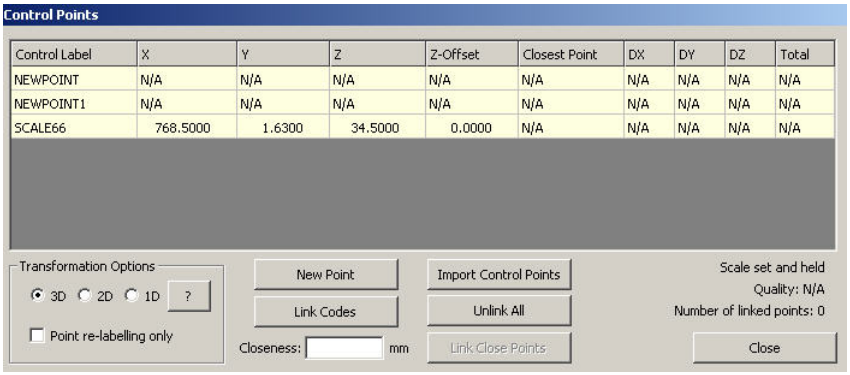


Figure 6.3

Once the desired number of control point entries is entered, simply highlight the cell in which a value is to be entered and insert the correct label/coordinate value, as shown in Figure 6.3. To remove a control point, right-click on the label and select **Remove**.

6.3 Transformation Procedure

The following procedure can be performed at any time after the 3D points measurements have been made, and after ensuring that the desired control points have also been referenced and therefore measured in 3D by *Australis*.

i) Because the transformation to control points process involves a point 'linking' operation, it is useful to initially have the 3D View open in the Workspace, with the point labels turned on (the **L** key). It might also be useful to have an image open for better visual interpretation of the control point layout. An example 3D View is shown in Figure 6.4.

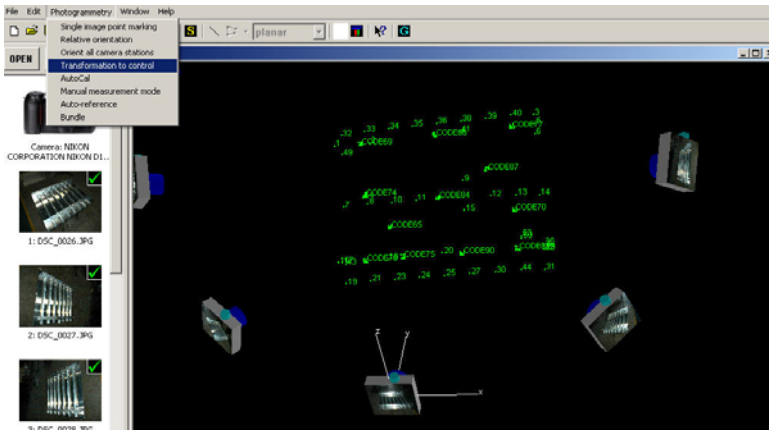


Figure 6.4

ii) The first step in the coordinate transformation process is to select **Transformation to Control** from the **Photogrammetry** menu, as shown in Figure 6.4. At this point the dialog box shown in Figure 6.3 will appear. This dialog has a window where the control point coordinates will be listed. Two actions are required here by the operator: First, the desired *transformation* must be selected by clicking the appropriate radio button (3D transformation is the default selection). Second, the control points need to be either imported from a control points file or interactively input.

Note on Scale: One of the two messages will be given in the dialog regarding the adopted scale of the transformed coordinates:

a) **Scale Set and Held** - scale has been set in the *Australis* project and will be maintained.

b) **Control Points Scale Adopted** - means that the final scale of the transformed coordinates will be that of the control points system.

The program will adopt option (a) or (b) purely on the basis of whether scale has been set in the project. If scale has been set in *Australis*, the user must first delete the scale information from the 3D View (ie no red scaled distances in the 3D View) in order to adopt the scale of the control point coordinates.

iii) Select **Import Control Points** in the case where control points are to be read from a file. The point labels and coordinates will then be displayed, as indicated in Figure 6.5. The control points text file can be built using an accessory program such as NotePad.

Control Points
Control Label | X | Y | Z | Z-Offset | Closest Point | DX | DY | DZ | Total
C-15 595.3000 743.6000 30.4000 0.0000 N/A N/A N/A N/A N/A
C-21 1383.6000 1246.7000 -0.9000 0.0000 N/A N/A N/A N/A N/A
C-33 1381.2000 0.0000 -0.0000 0.0000 N/A N/A N/A N/A N/A
C-40 178.9000 5.1000 41.2000 0.0000 N/A N/A N/A N/A N/A
C-44 184.5000 1253.0000 43.5000 0.0000 N/A N/A N/A N/A N/A
Transformation Options
3D 2D 1D ?
Point re-labelling only
New Point
Link Codes
Closeness: units
Import Control Points
Unlink All
Link Close Points
Control points' scale used
Quality: N/A
Number of linked points: 0
Close

Figure 6.5

iv) **Linking.** In order to match points in the 3D view or in the image(s) with the corresponding control points, a 'linking' procedure is adopted. First, highlight a point in the 3D View or image view (left-click and drag over the point) and then click the label of the corresponding point in the control points list (left hand column). This is illustrated

for 3D Points 21, 33, 40 and 44 (Control: C-21, C-33, C-40 and C-44) in Figure 6.6. Note that once the control point has been referenced, a green tick mark will appear. Also the label in the 3D view and images will change to that of the control point. If the point is the first to be linked, the coordinate origin will move to that point. Continue this process, ensuring that at least the minimum number of points for the desired transformation have been linked: 1 for a block shift, 2 for a 2D transformation, and 3 for a 3D transformation. A warning message will be displayed if a linked control point label is the same as an existing referenced point. The already referenced point will then have a '1' appended to its label.

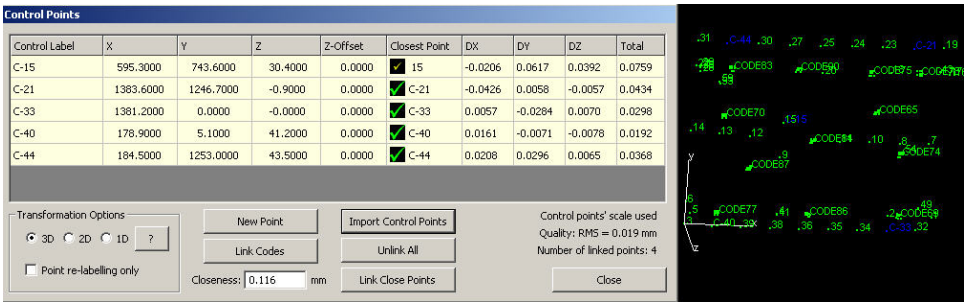


Figure 6.6

Note: When moving the cursor from the control point dialog box to the 3D View or the image view, the window for these two views may not become active until a cursor action is initiated. To activate the windows, simply left-click within the window.

v) **Linking via the List of Reference Points**. A second method to link control points to referenced points is to right-click on the control point label and select **Link to …** The desired point is then selected from the list of referenced points by left-clicking on the label in the referenced points list and choosing OK. This is illustrated in Figure 6.7.

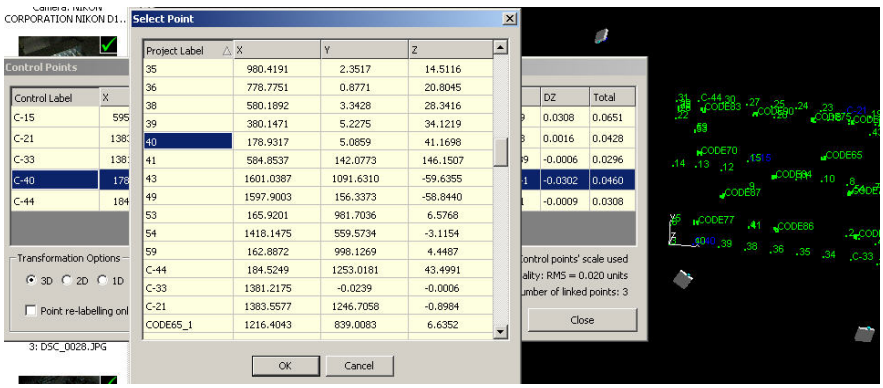


Figure 6.7

vi) The **Transformation Computation** will occur automatically, as soon as enough control points are referenced to their corresponding measured points. Upon transformation, the coordinate axes in the 3D View will move to correspond with the Control Point Reference System, as shown in Figures 6.6 to 6.8. At this time, 'transformation residuals' will be displayed in the columns headed DX, DY and DZ in the control points dialog box. In the case of there being more control points referenced than necessary, these coordinate discrepancy values can be used to indicate the quality of shape

correspondence between the measured and the control point networks. This is illustrated, by the example shown in Figure 6.8 where 5 points have been linked for a 3D transformation; the magnitude of the residuals indicates the level of shape/size correspondence between the two networks. Non-zero residuals will always be apparent for a 3-point 3D transformation. An overall quality value for the transformation, which is only applicable for cases of more control points than necessary, is indicated by the *Quality: RMS = *.***, which is shown in Figure 6.8 with the value 0.025 mm.

Upon transformation to control, the position of all control points will be shown in the 3D view in blue. The blue labels for these can be toggled on and off with the **N** key.

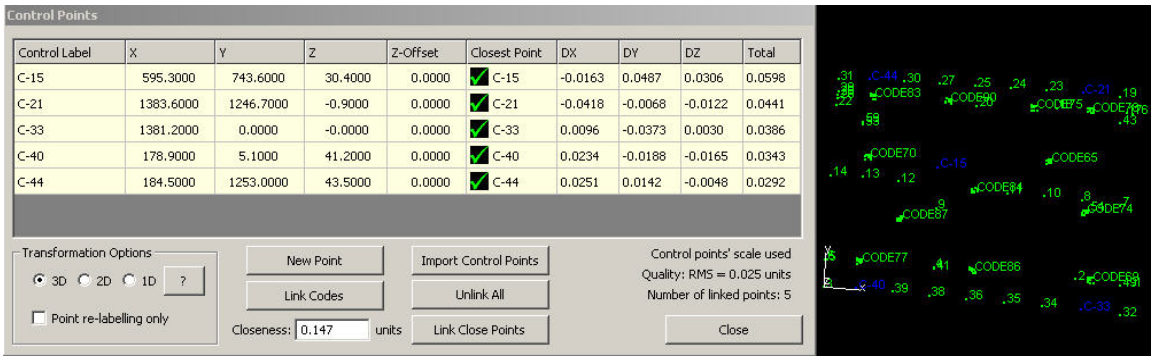


Figure 6.8

vii) **Linking Closest Points.** As shown in Figure 6.8, after a transformation solution is obtained a listing will be made of the referenced points which lie closest to the 'unlinked' control points. The distance discrepancies are indicated for the unlinked points in the columns DX, DY, DZ and Total (vector distance). In most cases, if the values are small & consistent with the DX,DY,DZ values for linked points, then there is a good chance that the closest point is also the correct point to be linked to the corresponding control point. To achieve an automatic linking of the closest points, simply choose the **Link Close Points** button, which will be greyed out until an initial transformation solution is obtained.

viii) **Unlinking Control Points.** In order to either unlink a control point, or remove the point from the control listing altogether, right-click on the control point and make the required selection. When a point is unlinked, a new point label is assigned to the corresponding point in the 3D view. This will also occur if a linked control point is removed. It is possible to unlink all points, but in doing so the XYZ coordinate system will remain in its current position.

ix) The transformation process is now complete and the **Close** button can be selected. If at any time following the transformation to control it is desired to again assign a new XYZ coordinate system, this can be achieved via the standard 3-2-1 procedure (Section 5). Similarly, scale can be re-set via the standard approach (Section 4).

6.4 Point Re-Labelling via Coordinate Transformation

There are many instances where object points are measured repeatedly, for example in deformation monitoring surveys where it is desired to quantify point movement over time. Because the automated referencing procedure assigns point labels automatically, the

numbering sequence for non-coded targets can change between repeat surveys. *Australis* offers a feature whereby point labels from a previous survey can be assigned to a repeat measurement through the coordinate transformation process. The procedure is basically identical to that for the 3D coordinate transformation to 'control', except that when a point is re-labelled it retains its original coordinates, i.e. there is no transformation of XYZ values.
To initiate the *Re-labelling*, select **Point Re-labelling Only** from the control points dialog (see Figure 6.8) and proceed through steps (iii) and (iv) of the coordinate transformation procedure i.e. import the control file & perform the linking, but with a relaxed *Closeness* value. Once linked, the 'control point' labels will be assigned to the corresponding object points.

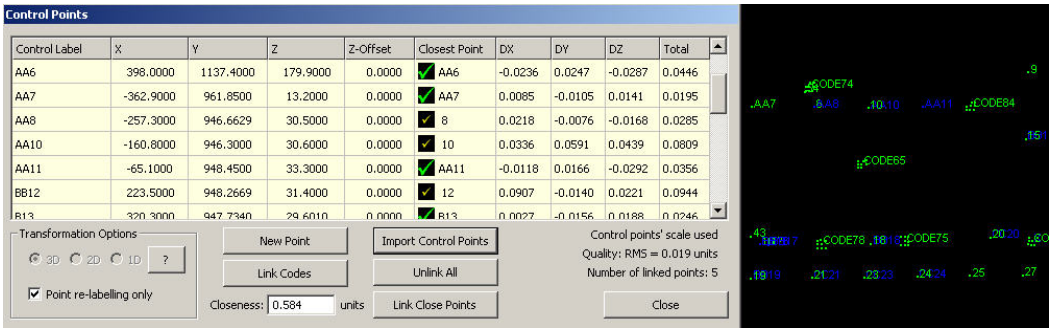


Figure 6.9

7. Quality Assessment and Results Summary

Australis updates the photogrammetric orientation and object point coordinates through a process called bundle triangulation every time a point is referenced. Thus, the final measured 3D data is always up-to-date and no special orientation processing step needs to be selected at any time by the user. If required, however, the bundle triangulation can be performed, as described in Section 3.4, by simply selecting the **B** button on the toolbar and then **Run**. This produces a summary of the bundle adjustment listing the number of points and images as well as other information, as shown in Figure 7.1. Clicking on the buttons labelled Camera(s), Stations or Points will give listings for these parameters, as shown for example for the camera stations in Figure 7.2.

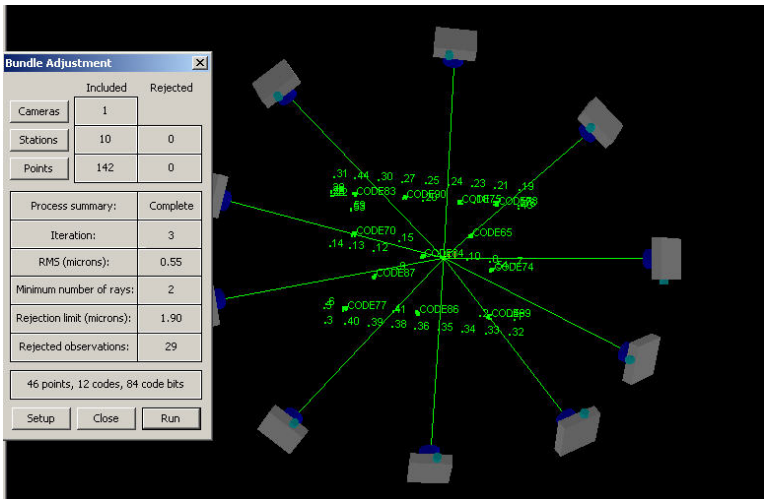


Figure 7.1

The observational error detection criterion for the bundle adjustment is set automatically within *Australis*. As mentioned in Section 3.4, a fixed *rejection limit* for the image coordinates observations can be set by selecting **Setup** (Figure 7.1) and then ticking the *Fixed* box and choosing the desired value. This option is generally not recommended as experience is necessary in selecting an appropriate value. The number of rays per target point can also be controlled via the *Setup* option. In a network with many images per point, this can be used to remove points from the bundle adjustment which are imaged by an insufficient number of rays, perhaps less than four in the network shown here, for example.

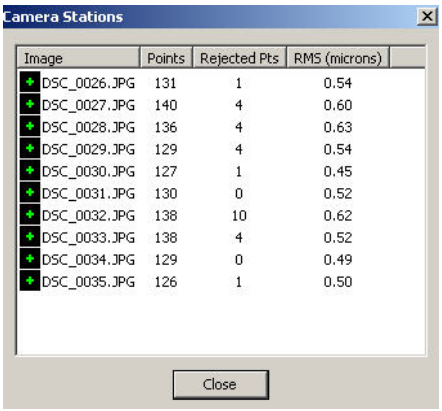


Figure 7.2

A further quality summary is provided for all oriented images via the selection of **Photogrammetry|Orient all Camera Stations**. This summary, shown in Figure 7.3, lists for each camera station the image name, orientation status, number of used observations, 'closure' value (RMS value of image coordinate residuals for the image), exterior orientation parameters and list of image coordinate residuals.

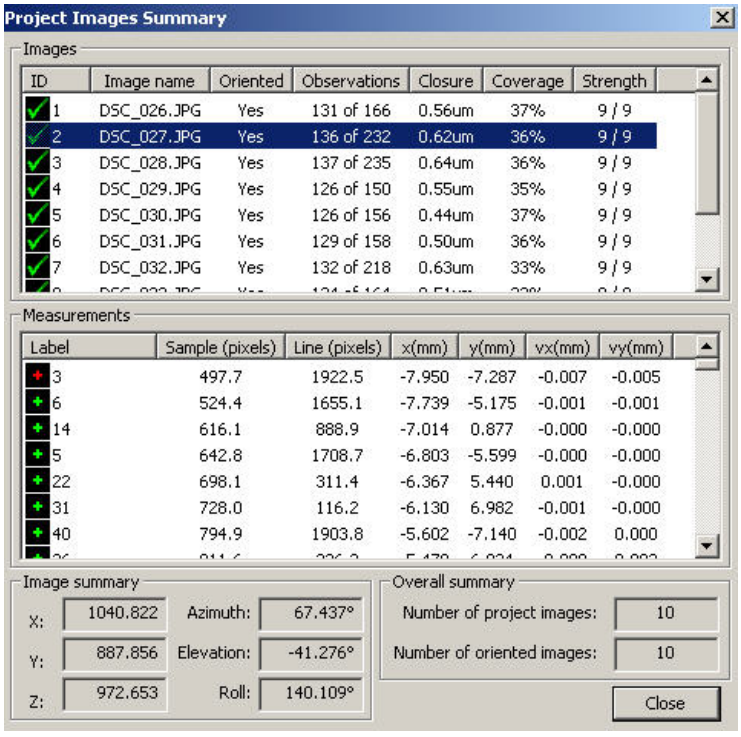


Figure 7.3

Prior to exporting the measured 3D coordinates, it is desirable to assess the accuracy of the overall photogrammetric survey. Information related to the quality of the full measurement process is contained in the *Summary*, which is available through selecting the **S** button on the toolbar. A sample summary is shown in Figure 7.4. This can be printed via the **Print** button.

Note the measurement accuracy summary in the figure. It states that scale has been set and that the individual 1-sigma accuracies for the X, Y and Z coordinates are 0.024, 0.023 and 0.029mm, respectively. The relative accuracies are also listed, as is the internal accuracy of the photogrammetric triangulation, which is here 0.07 pixels (1/15th of a pixel) suggesting a 0.6 micrometer accuracy for image coordinate measurements on the Nikon D100 images in this project. It is important to verify the quality of the results before the XYZ object point coordinate data is exported for further analysis.

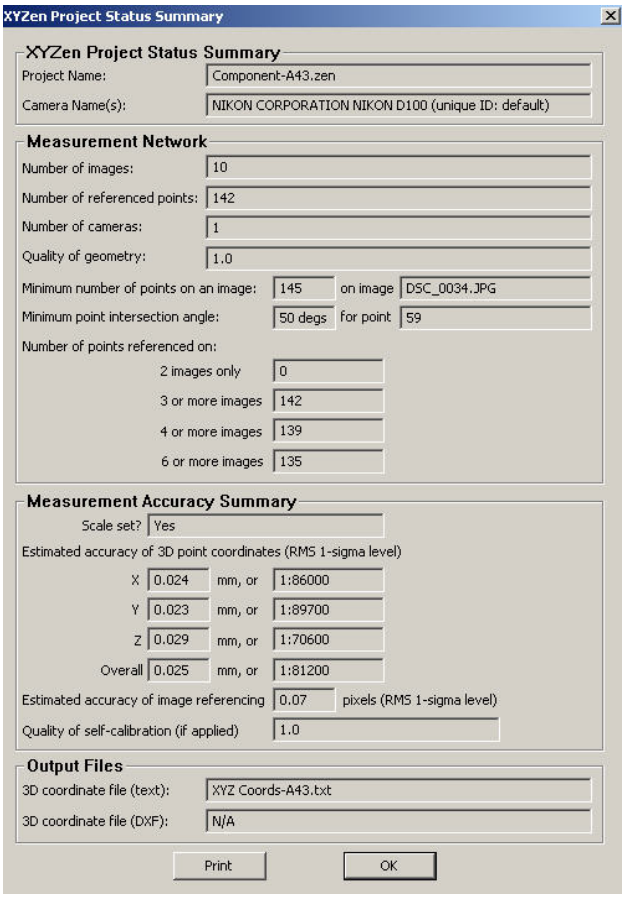


Figure 7.4

8. Exporting XYZ Coordinate Data

The final XYZ coordinates can be exported for further analysis and for CAD modelling purposes. There are two options, the first as a listing of XYZ coordinates and coordinate standard errors (sigma X, sigma Y, sigma Z) in an ASCII text file (*filename*.txt), and the second as a DXF-formatted file of XYZ coordinates (*filename*.dxf) which may include attribute data (eg lines, point identifier numbers, colours). To export the coordinates, select the XYZ coordinate list (button next to OPEN above the camera icon) and then select either of the **Export …** options.

Upon selection of **Export DXF**, the dialog box indicated in Figure 8.1 will be shown and the user is asked to select the text size for the DXF file. Also, there are four options. The first is to include a *Network Label Prefix*. The second is to write a 'dummy' origin point to the file, which is simply a record with the point label 'origin' and XYZ coordinates of (0,0,0). The third relates to whether the user wishes to output to the DXF file text descriptions entered for points. The default option for *Include descriptions* is to output the text point descriptor strings. The fourth option relates to the output of *Offset Points*.

There are also output options for **Export TXT**, as shown in Figure 8.2. These cover inclusion of code points, the ordering of the output ASCII file in alphanumeric order and the inclusion of the coordinate standard errors.

Figure 8.1

Figure 8.2

9. Automatic Camera Calibration

As briefly discussed in Section 3, the basic procedure for fully automatic camera calibration within *Australis* follows closely that for a normal automatic photogrammetric measurement. The only distinction is that the initial **AutoCal** procedure involves the use of coded targets alone. The user needs an array of preferably 20-30 coded targets. To illustrate the process here, however, we will simply use the same network as in the previous sections.

i) *Establish the target array*. Using the principles of having a well spread array which fills the image format and is preferably non-planar, establish a suitable target array. The array is shown in Figure 9.1. (Normally, more codes than 12 should be used).

ii) *Determine the camera station geometry and record the images as JPEGS* (at full resolution). The primary items to remember are that a) the camera station network provides strong convergence angles, b) The images are taken such that at least 3-4 of them are 'rolled' (90˚ rotation), c) the codes are distinguishable with each code dot being of high contrast and larger than 5 pixels in diameter in the imagery and d) it is preferable if all codes do not lie in the same plane. The geometry of the ship component survey, shown in Figure 9.2, is a good example.

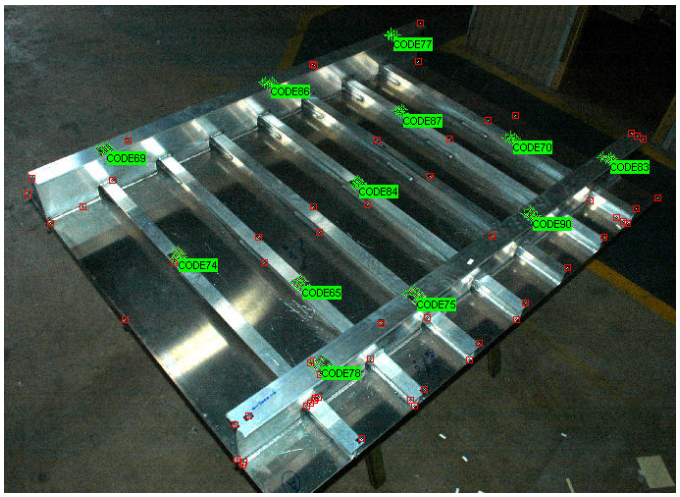


Figure 9.1

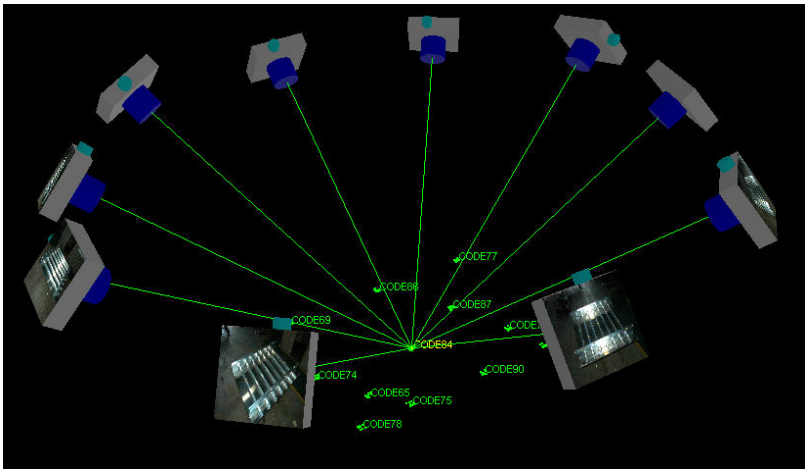
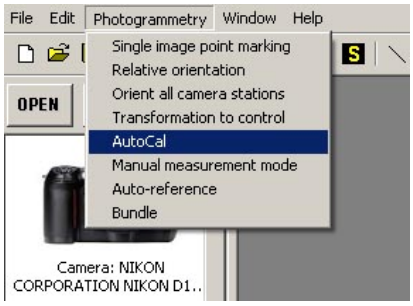


Figure 9.2

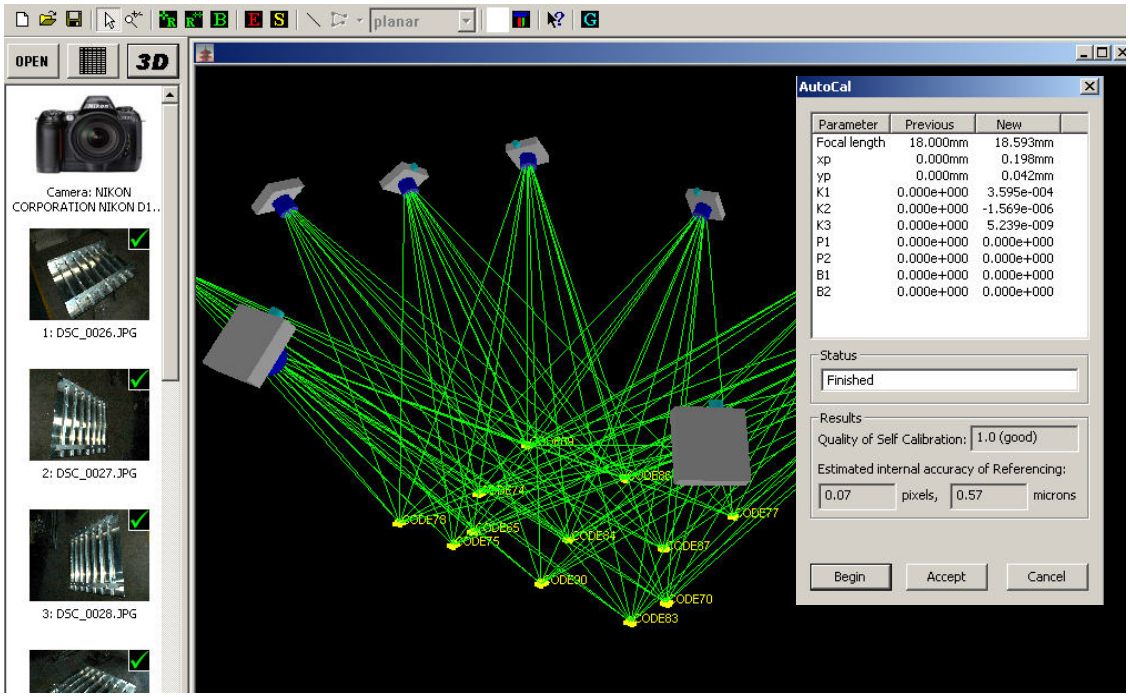
iii) *Load the images into a new Australis project in the normal way*, as described in Section 2. At this point the project camera will have been identified and the image thumbnails will be displayed in the thumbnail window.

iv) *Run the automatic calibration*. Select **AutoCal** from the **Photogrammetry** menu as in Figure 9.3. (same dialog box as in Figure 3.2). The operator then selects **Begin** and the automatic calibration proceeds. Each image is sequentially processed and once the calibration is complete the calibration results are displayed, as indicated in Figure 9.4.



Figures 9.3

v) *Save the calibration data*. Upon completion of the automatic calibration the user is asked whether he/she wishes to update the local camera database with the new calibration data. The normal response would be *Yes*. The project can then be saved and the process is complete.



Figures 9.4

10. Lines and Colour

Lines joining points can be drawn in both the 3D View and Image Views. The procedure for drawing lines, between just two points or between multiple points, is as follows:

i) Select the Line Cursor via the **Line** Button on the toolbar, the line cursor being a short line with a cross at each end. The cursor 'point' is the dot adjacent to the upper cross. The line cursor can also be selected in the image view using the **L** key.

ii) Click the **Colour** Button on the tool bar. This will generate the colour chart shown in Figure 10.1. Click on the desired colour and then click OK.

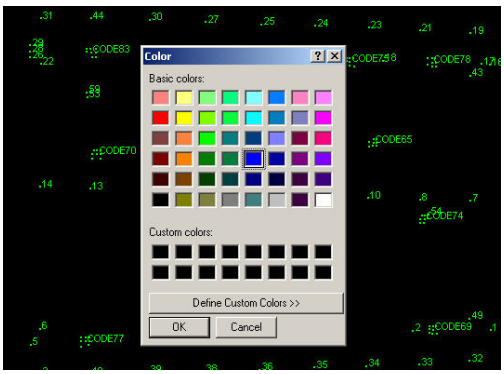


Figure 10.1

iii) In any of the image windows click on the first end point of the desired line and then on the second and subsequent points. To stop the line building, simply click again on the Line Button, click in the window away from any feature points, or use the ESC key on the keyboard. In the 3D view window, click on the first point and then hold down the CTRL key when selecting subsequent points.

iv) The resulting line will be drawn in the 3D view and in the images, as shown in Figure 10.2, and line attributes are output with the XYZ coordinates with the DXF export option.

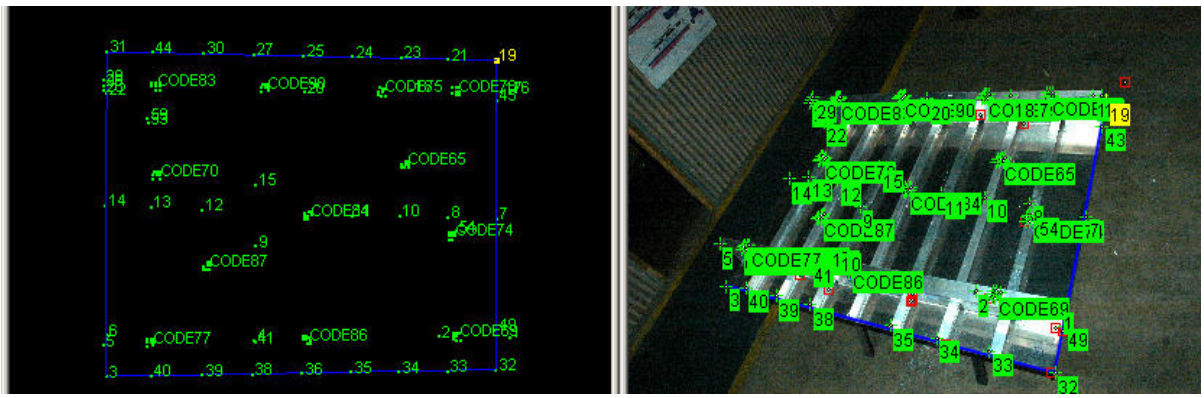


Figure 10.2

Alternatively, the user can right-click in the Image View while in Select Mode and choose **Line**. This brings up the dialog box shown in Figure 10.3. After selecting the two endpoint labels from the pull-down list, the line length will be displayed. The operator then chooses the colour and selects OK (twice if a new colour is set), at which point the line is displayed.

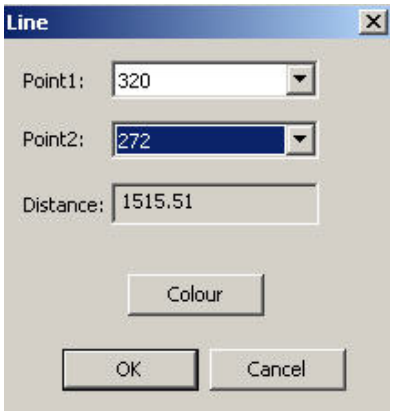


Figure 10.3

To **delete a line**, Select it in the 3D View and then use the DEL key on the keyboard. The **D** key can be used to toggle between show and hide lines in the Image and 3D Views.

Note on Line and Point Colour: To change the colour of a line or point (and label), highlight the line or point in the 3D View and click on the colour button. Then, select the desired colour and press OK. (The new colour will apply after the line or point is no-longer highlighted; ie click anywhere in the 3D View)

11. Point Referencing for Manual Measurement

11.1 Marking and Referencing

Following the automatic network orientation in *Australis*, it is possible to also measure the 3D coordinates of non-targetted points via a Referencing procedure. This manual process can also be used to initially orient images where coded targets are not available, but in this description it is assumed that an initial automatically measured 3D point network is in place. Such a situation is indicated in Figure 11.1.

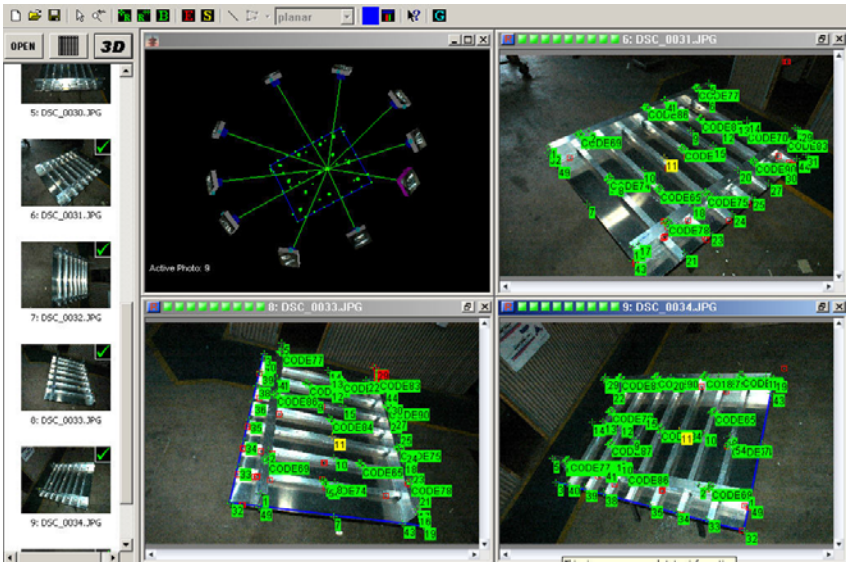


Figure 11.1

Imagine now that it is desired to measure an additional point, usually a non-targetted point. The procedure to do this is called referencing. Briefly, the actions to take are as follows:

1) *Enter Reference Mode:* To enter referencing mode, select either the green **R** button on the toolbar, or simply the **R** key on the keyboard. Or, when there are three or more images open, click on the red 'R' button on the image titlebar of the two images you wish to reference; the R button will then turn green. The cursor will now change to a green 'pencil'. Referencing simply entails the successive *marking* of the same point, sequentially in each image, with the order being either right to left or left to right.

Note on Navigate Mode: If at any time you wish to 'navigate' around the images, hold down the Space Bar on the keyboard and Navigate Mode will be selected. Left- and right-clicking in navigate mode zooms the image view. Recall also, that you can move the image by holding down the mouse wheel and moving the mouse.

2) *Reference the point(s) of interest:* The actual marking is illustrated in Figure 11.2. As shown, it is generally desirable to enlarge the image of the point to be marked. This is achieved through one of the four zoom options described in Appendix A.

With the pencil cursor positioned on the point of interest, click the left mouse button and a purple cross will mark the desired point. A sequence number, which has no importance at this stage, will also appear. This is the case in Figure 11.2. Then, move to the second image

where a blue line is shown, along which the correspond point should lie. (If the blue line does not appear, press the **B** key). A line also joins the marked point (with the pink label) and the green pencil. Now, go to the same point in the second image and mark the corresponding position. The two label markers now turn green and a number is assigned to the point.

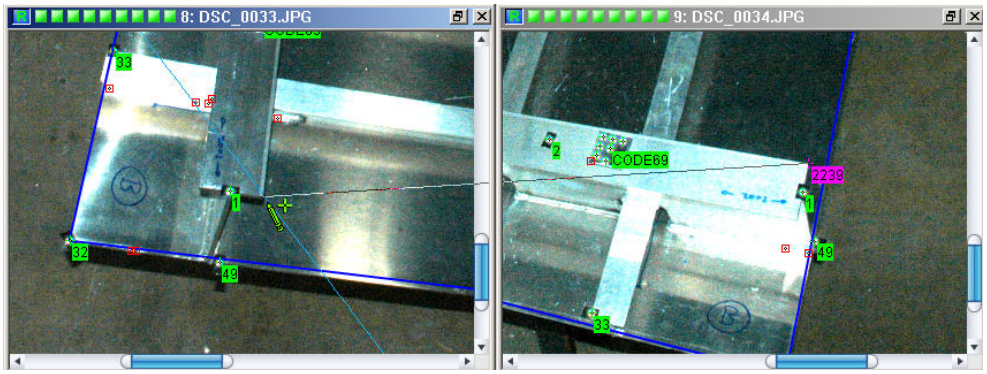


Figure 11.2

The point is now referenced and has 3D coordinates, but the accuracy will likely be significantly lower than the measurement of targeted points. Upon the successful referencing, the new point label (62 in this case) will appear in the Image and 3D Views, as shown in Figure 11.3 (the label is yellow instead of green here because the point has been highlighted/selected).

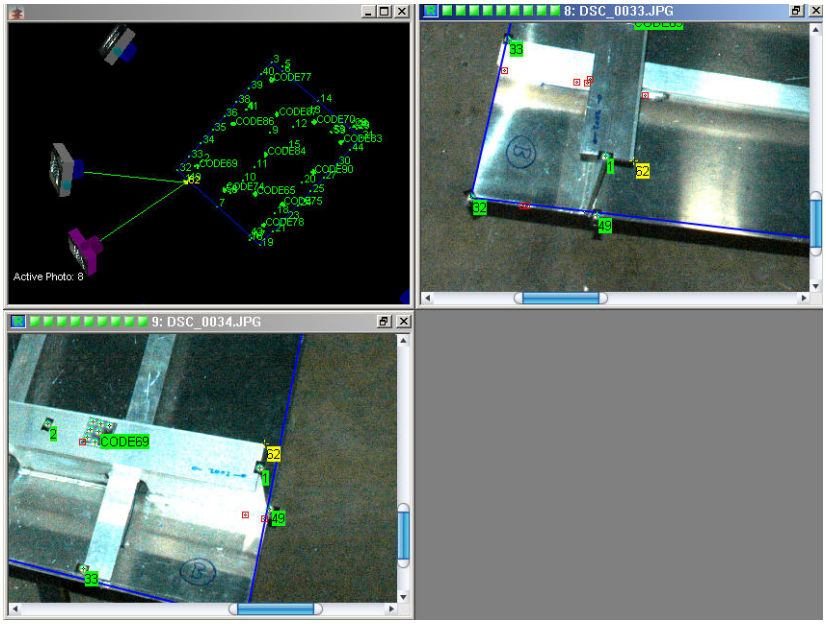


Figure 11.3

3) *Referencing Predicted Points:* After the new point is referenced (and therefore measured in 3D) in two images, its position can be predicted in all other images that see that point. These points are labelled in blue (if the 'blue' points are not displayed, move the cursor over the image and select the **B** key). So, if the user now chooses to reference the image point 62 in the third image, he/she must first un-click the *green R* button of one of two referencing images

and then click the *red R* of the image to be referenced. The *R* will turn green (or the user can turn referencing off and back on again via the **R** toolbar button or the **R** key). To reference the blue point, first click close to point 62 in the left image (green label) and then precisely mark the image point (don't just click near the blue label; its position is only predicted and may not be accurate). The blue label will turn to green and so point 62 is now referenced in three images. This process can be continued with other images and desired points.

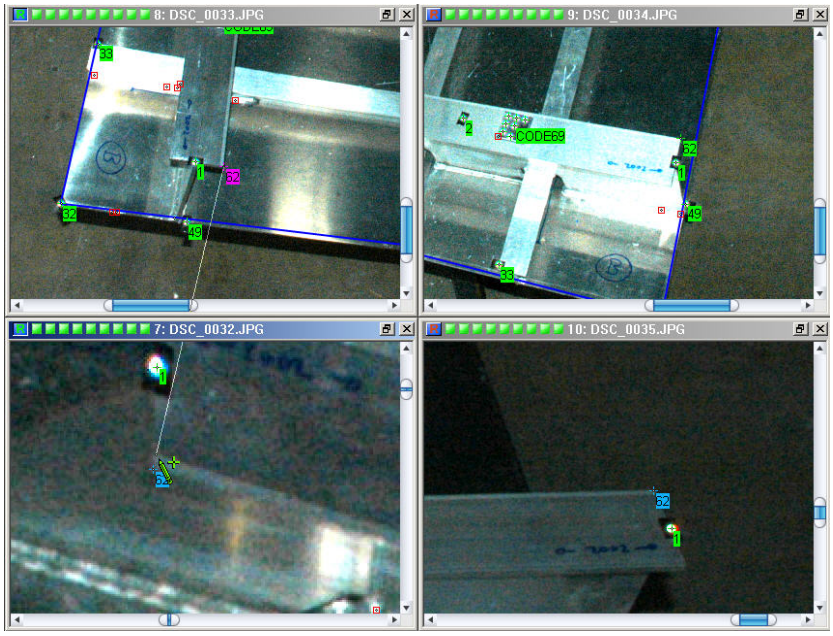


Figure 11.4

4) *Deleting a Point During Referencing*: Points are deleted during referencing as follows:

i) If the point selected in the first image (coloured purple) is deemed to be in error, use the Delete key to cancel the marking.

ii) For a referenced pair of points (while still in reference mode) hold down the CTRL key and the cursor will change to the Select cursor (arrow). A marquee box can then be drawn over the points(s) to be either unreferenced or deleted altogether. Also the point label in all images containing that point will turn yellow. Using the DELETE key will then un-reference the points and they will revert to red 'marked' status only (hence they are no longer 3D points). Clicking on these points in reference mode (after the CTRL key is released) will turn them purple and DELETE will remove them completely.

iii) When in reference mode, a right-click on the mouse will present the user with the option to either unreference or delete highlighted (yellow) points. For points already referenced in other image pairs, unreferencing will occur only in the current image.

iv) Finally, if the 3D view is open, the left-mouse button can be pressed and a box drawn over points to highlight them. They will again turn yellow, in both the 3D view and the images. The DELETE key will unreference these points and remove them from the 3D points list.

11.2 Undoing the Last Point Referencing

It is possible to undo the most recent point referencing operation by selecting **CTRL+Z** or choosing the pull-down menu selection **Edit|Undo last referenced point: #** (Figure 11.5).

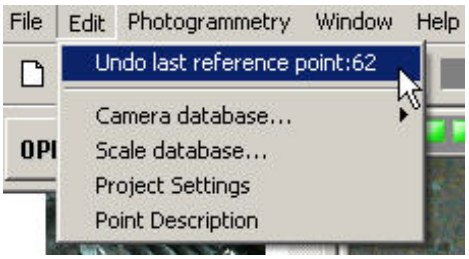


Figure 11.5

In the case where a point is already referenced, this operation un-references the point pair and deletes the new point marking. Through this function it is possible to undo referencing in the reverse order to which is was carried out, stepping backwards through the points.

Note on displaying images: It is possible to have multiple images open at different enlargements. It is thus often useful to return all images to full image view. To achieve this, simply use the **SHIFT + F** keyboard combination. To return a single image to full view, use the **F** key on the keyboard. Also, in order to close all images that are displayed, but not being referenced, either select **Window|Close NonReferencing** or call up the Select Cursor (use CTRL key when in reference mode), right-click and choose **Close Non-Referencing Images**. Finally, to evenly tile uneven windows, simply select either **Window|Tile** or **SHIFT+T**.

11.3 Target Centroiding

The optimum targets for precise marking and referencing are likely to be high contrast dots. Where such targets are utilised, *Australis* can fine-measure them during manual referencing with an auto-assist function that provides precise centre-of-target (centroid) determination. In order to perform an automatic precise marking in either Referencing or *Single Image Point Marking* mode (**Photogrammetry** menu, red pencil cursor), the Centroiding function can be employed. By selecting the **X** key for white blobs on a dark background, or the **C** key for dark blobs on a light background. (Recall: select Referencing or Marking mode first, followed by the centroiding function).

The centroid tool determines the precise centre (centre of gravity) of a target 'blob'. In this case the centre of target G in Figure 11.6 is required:

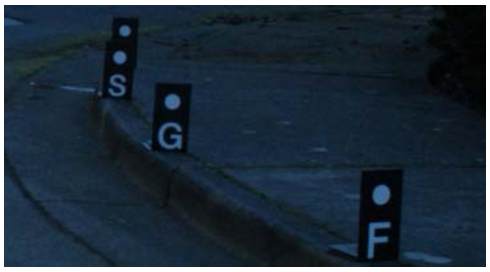


Figure 11.6

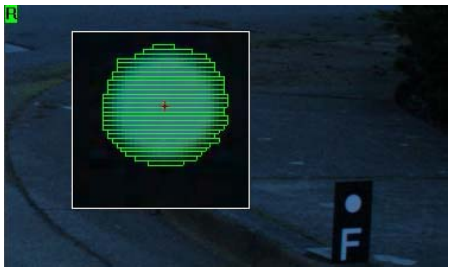


Figure 11.7

The centroiding operation proceeds as follows:

i) Select Referencing or Marking mode.

ii) The cursor is placed over the target and the **X** key (or **C** key for dark blobs) is selected; the zoom window then appears as shown in Figure 11.7.

iii) Moving the mouse within the window adjusts the intensity profile of the target, with the red cross always indicating the centroid (centre point). To see the image window clearly, simply move the mouse to the top right-hand corner of the zoom window. The aim here is to isolate an image blob which is distinct from its background, ie it has a closed border as indicated in Figure 11.8, and its red cross is stable with small movements of the mouse.

iv) A left-click of the mouse records the centroid position, as shown in Figure 11.9. A final centroid determination has thus been made to an accuracy that may well be 5 times better than with manual marking for suitably exposed high contrast targets.

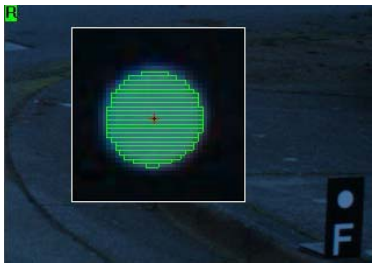


Figure 11.8

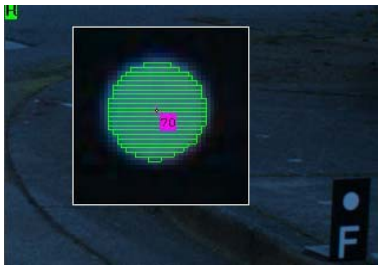


Figure 11.9

12. Review Mode

Review Mode, which is initiated by selecting the **Edit/Review** button on the Toolbar (Indicated with a capital **E**), allows a point-by-point review of all image point markings (ie image point referencing operations). As the name implies, Review Mode represents a final quality control procedure which is commenced once the network has been formed. It is really only appropriate for manually referenced points, so it will only be briefly described here. By presenting a visual display of every marking for a given point, as indicated by point 13 in Figure 12.1, the review process allows the operator to verify that the same physical feature point has been precisely marked in every image. If this is not the case, the operator can either move the marked point to the correct position or delete it if desired.

Caution: When the network contains many very large images (say 10 at >8mb each), **Review Mode** can be very slow to initially set up. Thus, it should be used infrequently for such networks, or even not at all. It is generally only appropriate for reviewing manually measured image points.

The review process is carried out as follows:

i) At the desired stage, typically after all images have been oriented and points referenced, select the **Review Mode** button on the toolbar (the **E** button). The workspace will then display the images. In Figure 12.1, the manually referenced point 13 is shown. Note the small dialog box which allows the user to move forward to the next point, move backwards to the previous point or move to any selected point (by selecting the number from the list). Also, the number of imaging rays to the point is shown, the maximum

intersection angle, and a Quality Value which is the RMS value of image measurement errors (in pixels) for the individual triangulated point. Values in the range of 0.05 to 3.0 would be expected for this. Finally, there are zoom buttons to further enlarge or reduce the images (all together).

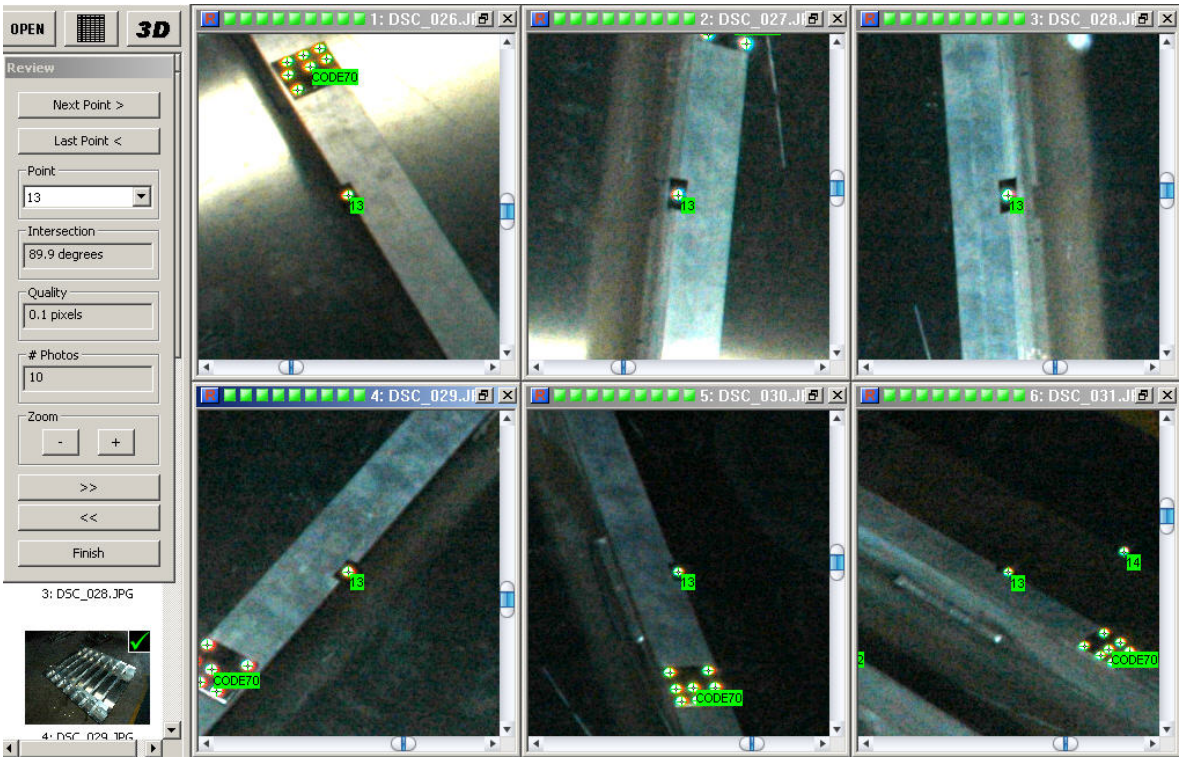


Figure 12.1

<u>Note on number of images displayed</u>: In Review Mode, only six images will be displayed at any one time. The operator can use the '>>' or '<<' buttons to move forward to the next subset of nine image chips of the point currently being reviewed, or back to the previous subset. Thus for a network with 36 images, the user must proceed, if desired, through six subsets of six image sets to review all possible images.

ii) The marked, referenced point in any image can be dragged to a new position using the blue pencil cursor and by holding down the left mouse button (if the blue predicted points are not being displayed, hit the **B** key).

iii) Every time a point is 'moved' in Review Mode, the full network is immediately recomputed, so small changes will be seen in the Point Table list, especially for the point being reviewed.

iv) In instances where multiple points appear in an enlarged image view, only the current point can be adjusted.

v) Where a point does not lie within the format of an image, a red cross will be shown in the centre of the image.

vi) On the other hand, if the ray from an object point to a camera station does fall within the image format then the predicted point location will be indicated in blue, as in Figure

12.1. It is now possible to mark and therefore reference this feature point, if visible, by simply positioning the cursor at the correct position and clicking the left mouse button.

Note: The operator can perform all the normal functions within the Review Mode images such as zooming, un-referencing points and deleting referenced points.

Upon completion of Review Mode (select the Finish button) *Australis* returns to the status it was at before Review Mode was selected.

13. Camera Selection and Camera Data Entry

13.1 Three Camera Scenarios

When images are loaded into *Australis*, one of three possibilities arises regarding the selection of the camera(s) and camera data:

i) The images contain an EXIF header which identifies both the camera and important camera parameters, especially the focal length. The *Australis* camera database already has details of this camera, so basic camera information can be immediately associated with the images in the project. This case, covered in the Section 2, is the most common that *Australis* users with newer digital cameras and JPEG imagery will encounter.

ii) As in (i), the images contain an EXIF header, but the camera is not in the *Australis* database. The camera will then be new to *Australis* and although certain camera information will be available from the EXIF header, the user may need to enter additional camera values. This scenario may arise when using a newly released camera.

iii) The final scenario is where the images have no EXIF header and so *Australis* cannot determine from the imagery alone the make, model and calibration parameters for the camera. In this case the user will be prompted to enter important camera data before proceeding further with the project.

The procedure associated with each of these scenarios will now be summarised.

i) ***Camera Case 1:*** *Image files contain camera information, and the camera data is already in the Australis database*

The procedure for this most frequently encountered case has already been described in Section 2.2. In this section, therefore, only a brief summary is presented for this camera scenario. As will be explained in Section 13.2, there can be multiple sets of calibration data in the *Australis* database for a given camera. If there are two or more such entries, the dialog box shown in Figure 13.1 is displayed when the images are imported into the project list. The desired Unique ID (Section 13.2) needs to be selected in this case.

Figure 13.1

Upon the images being imported, the camera thumbnail will appear, as shown in Figure 13.2. This means that the camera associated with the images has been recognised,

and that it exists in the *Australis* database. Multiple cameras can also be accommodated within the one project.

Note Regarding Image Resolution: It is highly recommended for accuracy reasons that the digital camera be used at the 'correct' resolution setting. It is best not to use resolutions where the image dimensions (in pixels) are either higher or lower than the pixel dimensions of the camera. If the camera is 3008 x 2000 pixels, then use the image resolution of 3008 x 2000.

A list of the camera parameters can be generated in the main window by double-clicking on the camera icon, this list being shown in Figure 13.2. Calibration values can be changed interactively, though this is only infrequently required for the case of a previously calibrated camera already residing in the database. Caution must be exercised in altering camera calibration values. If nothing is known of these, other than the approximate focal length value which must always be entered, the values should be left at either their previously calibrated values, or at zero.

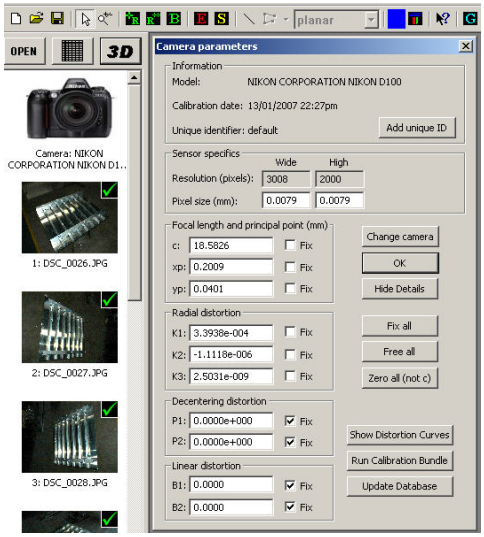


Figure 13.2

Note: If the focal length in the EXIF Header is more than 1mm different from that for the same camera in the database, a new **Unique ID** for the camera should be set at this time. This will create a second set of calibration parameters, as explained in Section 13.2.

ii) ***Camera Case 2:*** *Images contain camera information, but the camera is not in the Australis database.*

In the case where the images have EXIF header information about the camera, but the camera data is not already in the *Australis* camera database, the warning message shown in Figure 13.3 is displayed to indicate that some camera data will need to be entered before the project images are loaded.

Figure 13.3

Upon selection of OK, the camera parameters dialog shown in Figure 13.4a will be displayed. The User needs to check the listed camera values and enter any calibration values (Figure 13.4b). The camera make and model cannot be changed as this is read from the EXIF header.

A valid (non-zero) entry must be made for the focal length, whereas other entries need only be made if the correct values are known. Otherwise, leave the entries (except the focal length) at the default values displayed. The default pixel size is set to 0.005mm. A typical range for consumer digital cameras is 0.003mm to 0.009mm, and it is desirable – though not mandatory – to enter the correct value here if it is known. Adoption of the default pixel size will lead to a satisfactory camera calibration and subsequent 3D measurement, but the computed focal length (principal distance) may differ from that indicated for the lens. Once the required entries are made, click OK and the camera is then added to the *Australis* database.

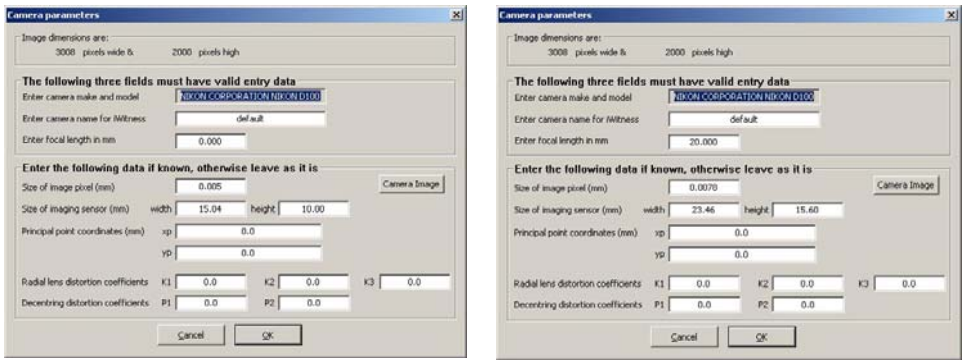


Figure 13.4

iii) ***Camera Case 3:*** *Images contain no camera information; the camera may or may not be in the Australis database*

When images have no EXIF header the following warning message appears: *No camera found in EXIF Header … Camera must be selected manually*. After OK is selected, all cameras in the *Australis* database that have matching image dimensions will be listed, as shown in Figure 13.5 (the list may well be empty if there are no such matching cameras). The operator can now either select a camera from the list by highlighting it and choosing **Select**. Or, the operator can choose to **Add New Camera**. It is also possible to delete a camera from the camera database via this dialog (use **Delete Camera**).

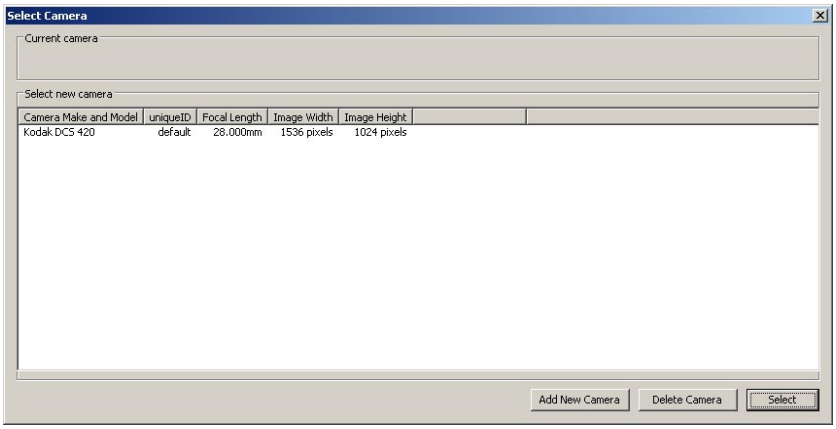


Figure 13.5

If **Add New Camera** is selected, the operator needs to go through the same procedure as in the previous case (Camera Case 2), except that here an entry for the camera make and model must also be made. An example completed entry is as shown in Figure 13.6.

The first three (compulsory) fields in the camera parameters dialog will always initially contain 'not set' for the make and model, 'default' for the camera name and 0.00 for the focal length. The first and third field must have valid entries. The Tab key is used to move between fields. Once the camera information is entered and OK is selected, the camera list in Figure 13.5 is updated with the new entry. The operator then needs to highlight this newly entered camera and choose **Select**. The project images can then be loaded in the normal manner.

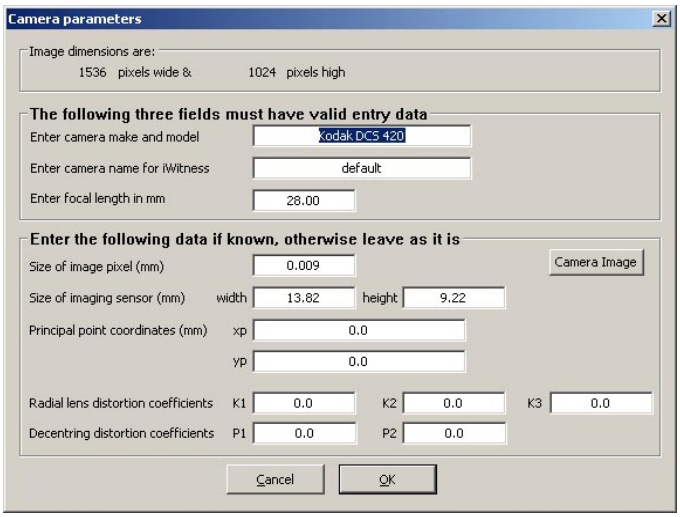


Figure 13.6

13.2 Unique Camera Identifier (Unique ID)

The important camera calibration parameters of focal length (principal distance) and lens distortion vary with focus and zoom settings for a lens. The possibility then arises, that for a given camera in the *Australis* database, multiple sets of calibration data might be needed if the camera is employed either at different lens focus, or with different lenses or zoom settings.

This can create difficulties because the same camera name, etc. will be read from the EXIF header in the images, but the essential calibration data, which may or may not be known for the particular lens and focus, will be different to that stored for that camera in the database. *Australis* overcomes this problem by assigning ***Unique Identifiers (Unique IDs)*** to given camera/lens/focus combinations. The procedure for assigning a Unique ID, which is essentially a new entry for an existing camera in the database, is as follows:

i) Within the Camera Parameters dialog, which is opened by double-clicking on the Project Camera icon, there is a button labelled **Add Unique ID** (See Figure 13.2). Selecting this button will produce a further dialog box as shown in Figure 13.7a.

ii) The Unique ID for the camera setting of the project, for the camera named in the title bar of the dialog in Figure 13.7, can then be entered. An example is shown in Figure 13.7b.

iii) At this point the unique ID will be added to the existing list of IDs for that camera. There may already be more than one ID, but there will always be at least one, this being the

'default' ID. If a camera has only one set of calibration data recorded in the database, then it does not need a Unique ID.

Subsequent selection of **Add Unique ID** will show all IDs listed (Figure 13.7c). The dialog will now also show the Unique ID and the parameters related to that camera setting.

(a) (b) (c)

Figure13.7

13.3 Changing Cameras

The user may wish to change the camera (and camera parameters) associated with the project images (either a single image or a group of images). For example, it may be desired to change from the default camera to a calibration set associated with a particular Unique ID. There are two ways to change the project camera:

i) The most common procedure will entail double-clicking on the Project Camera icon and then selecting the **Change Camera** button in the Camera Parameters dialog box (see Figure 13.2). This will open a list of cameras, from which the desired camera/Unique ID combination can be selected. After clicking on the desired camera, select the **Change** button. Note that only cameras with the correct image dimensions will be displayed.

ii) A second way to invoke the **Change Camera** function is to right-click on one of the image thumbnails. The procedure is then the same as in (i), except that in this case only the image concerned will be assigned the new camera.

13.4 Camera Databases

Australis utilises two camera database files: a read-only 'global' database and a 'local' database. All cameras utilised in projects will be entered into the local database. Thus, whenever *Australis* searches for a camera, it first looks in the local database, after which it accesses the global database. The distinction between the two is not apparent to the user. The global database is 'read-only' so that no editing of this is allowed. On the other hand, cameras can be added or deleted from the local database, as required, through normal *Australis* operations. Descriptions have been given as to how to add a camera to a project, and hence to the local database, and how to delete a camera from the local database via the Change Camera option. To delete a camera from the camera database, select **Edit|Camera Database|Local**, as indicated in Figure 13.10. This then brings up the dialog box shown in Figure 13.11, which lists all cameras in the local database. To delete a camera from the list, and therefore permanently from the local database (but not the global database), highlight the camera and select **Delete**.

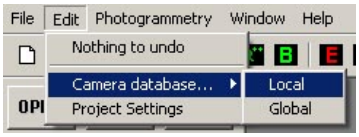


Figure 13.10

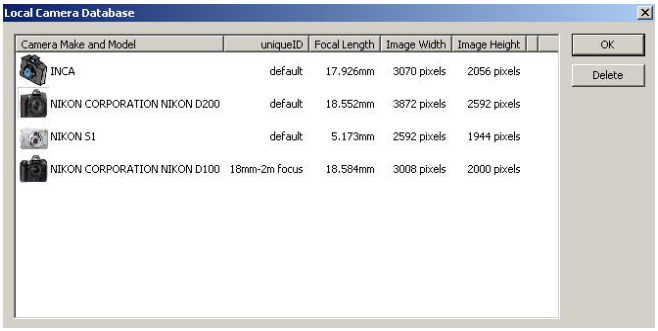


Figure 13.11

13.5 Listing the Global Camera Database

To list all cameras in the Global Camera Database, select **Edit|Camera Database|Global**. The user can then scroll through the list of cameras, but cameras cannot be added to or deleted from this list.

14. Generation of 3D Polylines

14.1 Polyline types

Previous versions of *Australis* have supported only 3D point determination from the referencing of corresponding image points in overlapping images. Sometimes, edge detail and curved features are found where point referencing is difficult or not feasible. In such cases it is now possible to determine *3D Polylines*, which do not require the specific referencing of corresponding image points. *Australis* can generate two types of polylines:

i) Facet polylines, which are best suited to geometric figures whose boundary points (eg corners) are recognisable in multiple images.

ii) Free-form polylines, which are best suited to defining curved lines, a straight edge being the simplest case.

Two examples of polylines are shown (in selected or highlighted mode) in Figure 14.1. The arch above the door is a 3D *free-form polyline* generated from non-corresponding point markings, whereas the rectangle at the top of the door is a *facet polyline* that has corresponding corner points, but note that these are not referenced points. The arch could also have been generated via the *facet polyline* method. Both polylines in Figure 14.1 were referenced via the two right-hand images, with their positions in the lower left image being from back-projection (equivalent to blue, predicted points). Their 3D location is shown via the *3D View*.

Cautionary Note

The generation of polylines is an inherently less accurate and often less robust procedure than the creation of single 3D points through referencing. Indeed, there are many possible image

geometry configurations where the polyline determination will be subject to systematic error, and may even fail. Consequently, care needs to be taken to ensure a) that the project will produce accurate polyline information, and b) that polylines free of systematic error are being generated. This can be checked in part via visual assessment of the back-projected polylines in non-referencing images.

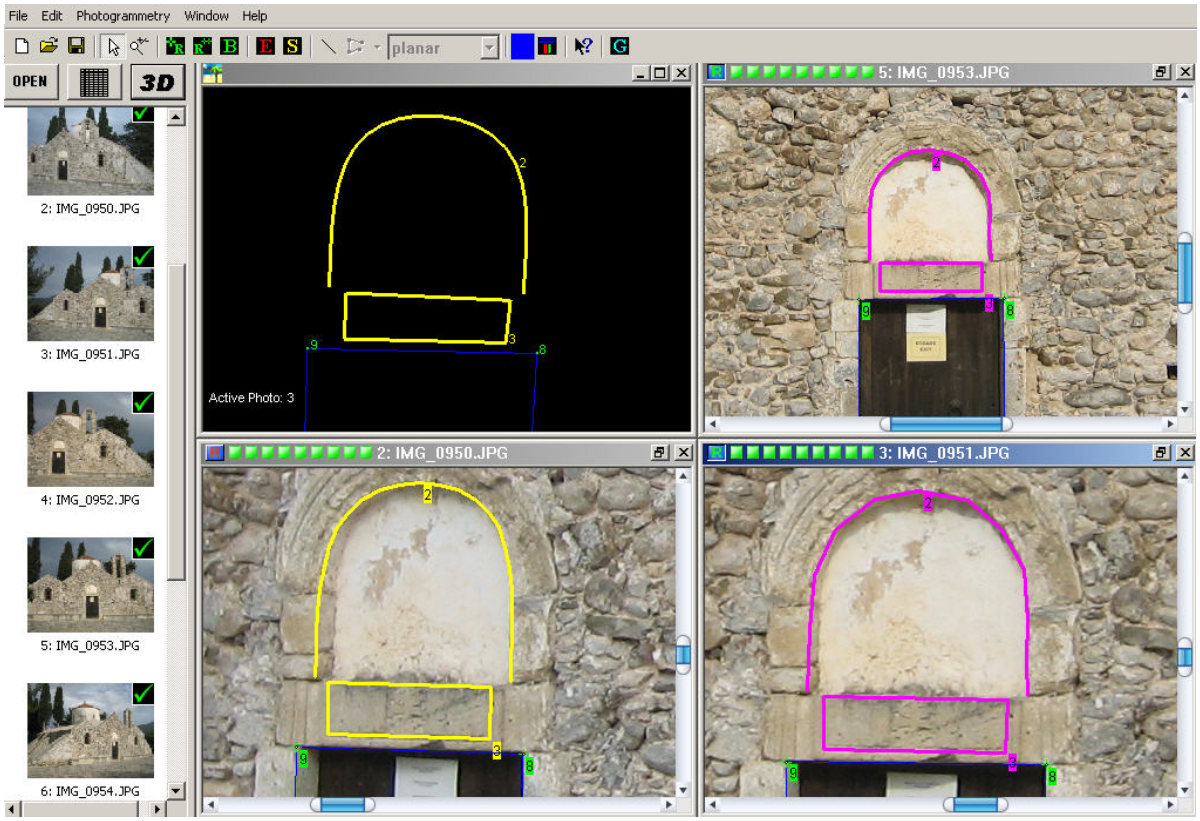


Figure 14.1

14.2 Polyline Creation

The following procedure is adopted to create a 3D polyline:

i) In order to draw polylines, switch to the *Polyline Marking Mode* by selecting on the toolbar. This is only possible in *Referencing Mode* . Either *Facet* or *Free-form* polylines are available, as mentioned above and detailed later.

ii) You can create a polyline now in one of the two referencing images by clicking the left mouse button along the desired object. Select as many points as necessary to approximate the object. If you are not happy with a point, press **backspace** to undo the last clicked point. To cancel the whole drawing process, press the **ESC** key.

iii) To stop adding more points to the polyline, click the right mouse button. The polyline will change colour to purple, which advises you that any new polyline drawn on the other images will be referenced to this polyline.

iv) Go to the second referenced image and create a polyline along the same object as described in ii) and iii).

Important note: Use the same drawing order for both polylines. After the second image polyline is created *Australis* is able to calculate a 3D polyline.

v) Open the 3D View to see the result. You can also open a third image to see the back-projected (predicted location of the) polyline. This will be shown as a dotted blue line. To turn the back projected polylines off, press **N** on your keyboard.

In order to calculate a polyline from more than two images, do the following:

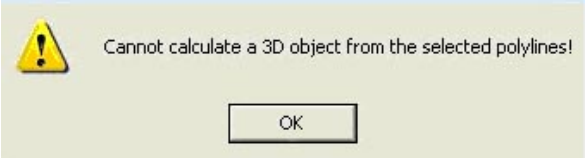
1) Make sure that you are in *PolyLine Marking Mode* and that the polyline object you want to measure is present in one of the two referencing images.
2) Highlight the polyline you want to measure (the colour of the highlighted polyline will change to purple).
3) Now follow steps ii) and iii) above, again to measure the polyline. After the right mouse click, *Australis* will recalculate the polyline in 3D from all measurements.
4) The *3D View* and the back projected polylines are updated automatically.

If *Australis* is unable to calculate the 3D object, one of the following error messages will appear:

Reason: An attempt was made to reference closed and non-closed polylines, which is not possible in *Australis*. The type of the second and subsequent polyline measurements must match the first drawn polyline.

Reason: This error-message appears, when the user attempts to reference ‘Free’ and ‘Facet’ polylines together. The polyline type of the second and subsequent referenced polylines must match the type of the first drawn line!

Reason: *Australis* was not able to determine the common start and/or end points between two or more referenced polylines. **Suggestion**: if this message occurs, try to use exactly the same start and end points rather than using different points.



Reason: This error message can appear for several reasons, but if it occurs while using the *free-form polyline* mode, instead try using *facet polylines*. In most cases this will give the desired result.

14.3 Selecting, Deleting and Colouring Polylines

In order to select a single polyline, either click close to the polyline in one of the images (or *3D View*), or use marquee dragging (left-mouse click and dragging) over the whole polyline. To select more than one polyline, hold down the CTRL key and click close to the polylines or enclose the desired polylines with the marquee tool.

To delete one or more polylines, highlight the desired polylines and select the **Delete** entry from the menu by clicking the right mouse button in either the *Image View* or the *3D View*. Alternatively press the **DEL** key on your keyboard.

Polylines are drawn in the current selected system colour. To change the colour of an existing polyline, first highlight it, then click the colour button in the toolbar, choose a colour in the dialog and press OK.

14.4 Polyline Information Dialog

To view information about a polyline, highlight it and press **P** in either one of the images or the *3D View*. This will produce the dialog shown in Figure 14.2.

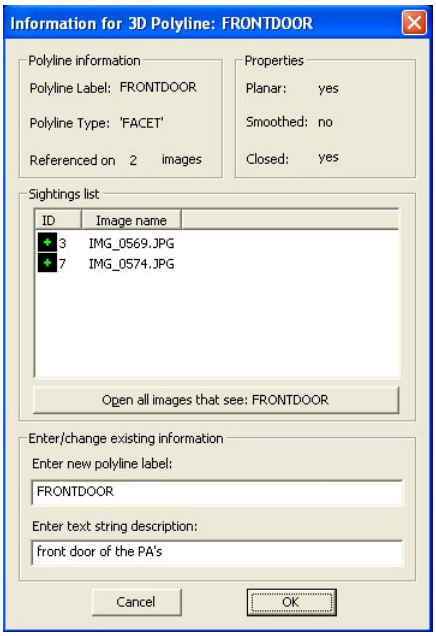
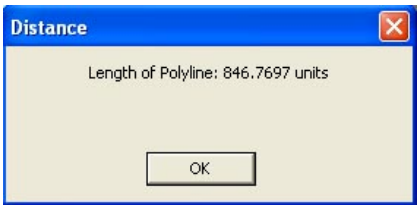


Figure 14.2

In order to change the default label, or to add a description for the polyline just change the entries *new polyline label* and/or *text string description* and press **OK**.

14.5 Polyline Length

To determine the length of a polyline, highlight it and click the right mouse button in either one of the images or the *3D View*. Select **Distance…** from the menu. Depending upon the units used and whether or not the scale is set, a dialog similar to that below will appear, listing the length of the polyline. If more than one polyline is selected only the length of the first polyline is displayed. The length of a selected polyline is also displayed in the *3D View*.



14.6 Closed Polylines

Both closed and open (non-closed) polylines can be created. To close the polyline being working on, move the mouse pointer to the first clicked polyline point. A small rectangle over this point will then appear. Just press the left or right mouse button and *Australis* will close the polyline automatically.

Important note: As previously mentioned, it is not possible to mix closed and non-closed polylines in the calculation of a single 3D object.

14.7 Facet Versus Free-Form Polylines

Australis provides two different ways to draw polylines – the *Facet* and *Free-form* methods. The preferred method is *Facet* as this usually leads to more accurate and reliable results.

The *facet polyline* method provides the capability to define polylines using discrete points (such as distinctive corners, edges, pixel brightness variations, etc) where it is possible to see common points between images. Of course this restricts the choice of points as the polyline needs to be defined by corresponding points in the images. The polyline can start and end on different points, as illustrated in Figure 14.3 below. Notice that the resultant 3D polyline will consist of only the common segments measured between the images.

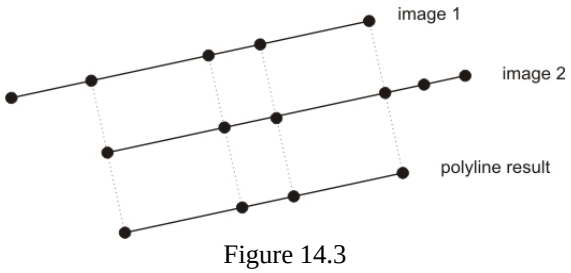


Figure 14.3

Since common points are selected with *Facet polylines*, *Australis* suggests the next point to be measured on the referenced polyline. Additionally, a guiding line is shown in the image in which the polyline is currently being marked, as shown in Figure 14.4. To change to the next

suggested point press the + or – key. This is a perfectly valid thing to do, as it is not necessary to start and end a *Facet polyline* exactly at the same points as the referenced polylines. This may be the case for example if the first point of the polyline is not visible on the image currently being marking – in this case, press the + key to go to the second point. It is also possible to measure beyond the initial polyline's length. If this is desired, ignore the suggested point on the referenced polyline.

With the *Free-form* method, it is not necessary to start and end polylines with common points, though common points generally produce a more stable and reliable result. The points marked in between the first and last point of a *Free-form polyline* do not necessarily have to have corresponding points on the equivalent polyline in the other image(s). The most important thing is to try to describe the object as well as possible in all images. All *Free-form polylines* are smoothed by default.

Recall that it is possible to close both types of polylines.

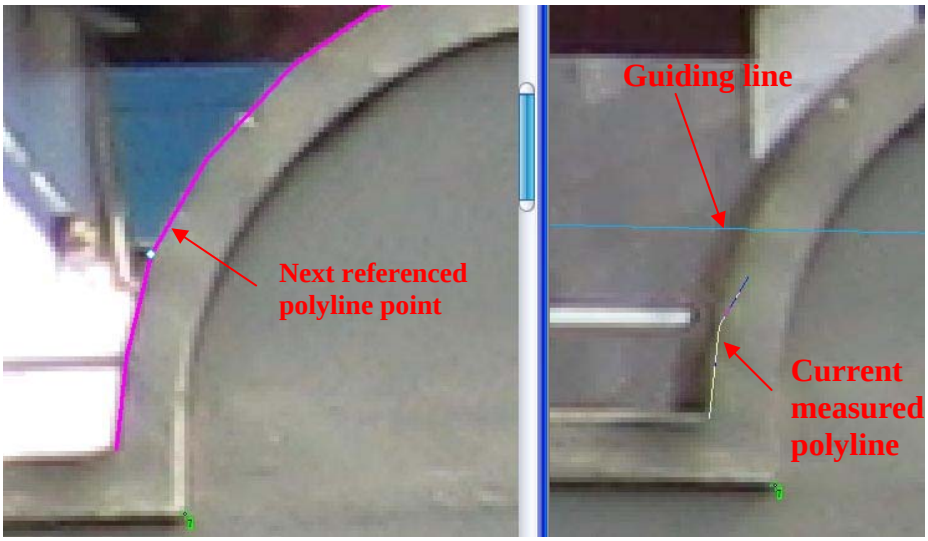


Figure 14.4

To **change** between the two polyline modes, click the down arrow next to the polyline button on the toolbar and select the desired mode. This will change the icon of the polyline button to either for *facet* or for *free-form*, depending upon which method has been selected.

Examples of *facet* and *free-form polylines* are shown in Figure 14.5.

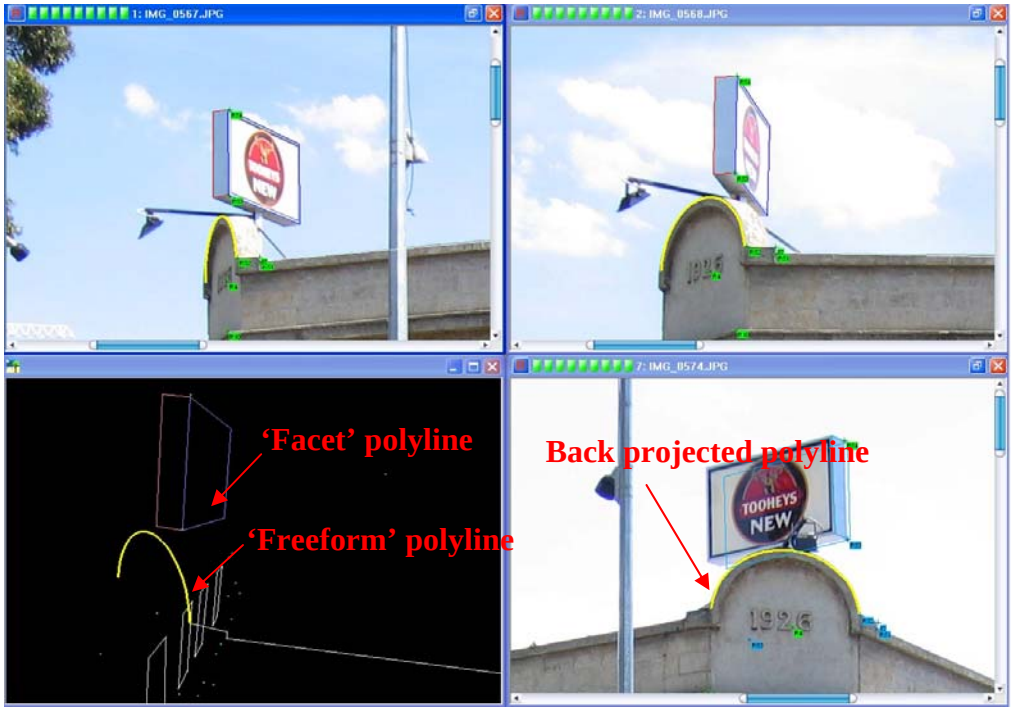
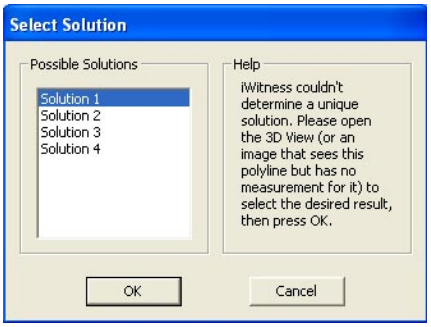


Figure 14.5

14.8 Ambiguous Polyline Solutions

Sometimes the operator will have to mark a polyline where the blue guiding line closely follows the path of the actual object feature being measured. For example, the blue guiding line may be parallel and overlapping the white road paint that defines the edge of a lane. In such cases *Australis* may have problems in determining a unique solution, and this is caused by the overall geometry of the camera station network. The dialog below, which lists all possible solutions *Australis* can determine, will then be shown. To help select the correct solution it is useful to open the *3D View* as well as a few additional images in which the polyline is back projected. The selected solution in the dialog will be shown in the open views so that the correct solution can be visually determined. Once **OK** is selected, there is no way to change it, so care must be taken to ensure the correct solution is chosen.


Select Solution
Possible Solutions
Solution 1
Solution 2
Solution 3
Solution 4
Help
iWitness couldn't determine a unique solution. Please open the 3D View (or an image that sees this polyline but has no measurement for it) to select the desired result, then press OK.
OK
Cancel

14.9 Planar and Non-Planar Polylines

Quite often the object featured being measuring using polylines in the images are planar, for example building facades, road surfaces, car panels, etc. A planarity constraint can be added to ensure the polyline lies within a plane. Alternatively, the planarity constraint can be

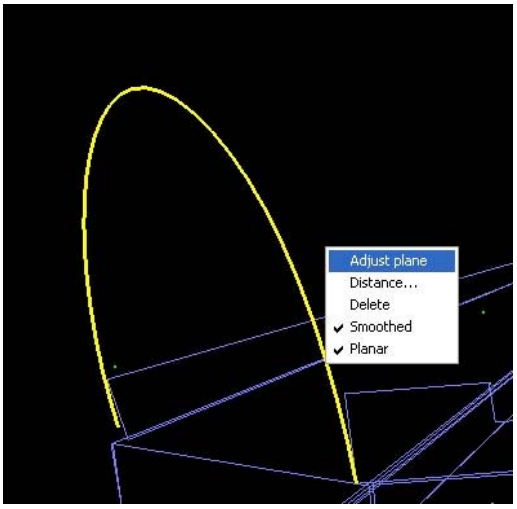
removed for non-planar cases. This option is only available in *PolyLine Marking Mode* or when a polyline is highlighted/selected. The default selection is to impose the planar constraint, with the choose being made through the pull-down menu from the toolbar:

There are three ways to add/remove the planarity constraint:

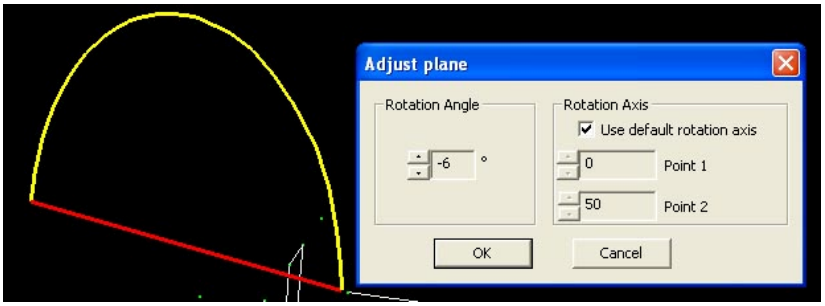
1. When activating the *PolyLine Marking Mode*, choose the polyline method (*Free-form* or *Facet*) and the constraint in advance. Every newly created polyline will use these settings.
2. Highlight one or more polylines and select either *planar* or *non-planar* from the toolbar. The 3D object(s) and all the back projected polylines will be changed immediately to reflect this.
3. Highlight one polyline and press the right mouse button in the *3D View* to bring up the menu; then select Planar to add/ remove the planar constraint.

Once the planarity constraint is added to a polyline, it is possible to adjust the adopted plane by changing the rotation angle and rotation axis. To change the rotation angle and axis, use the following procedure:

i) Zoom to the desired polyline in the *3D View*. It is also a good idea to open one or more image(s) where the back projection of this polyline can be seen.
ii) Select one polyline in the *3D View* and click the right mouse button. In the menu displayed, select **Adjust Plane**.



iii) Notice the red line below; this is the rotation axis. Use either the default rotation axis or adjust the axis by unselecting *Use default rotating axis* and changing the line points considered for the rotation.



iv) Change the rotation angle until you are satisfied with the back projected polylines in the images.

v) Press **OK** to save the rotation axis and angle.

14.10 Smoothed and Non-Smoothed Polylines

Australis provides the possibility to smooth polylines as a post process. By default *Free-form polylines* are smoothed, but they can also be unsmoothed. *Facet polylines* may also be smoothed where it is appropriate to do so. To toggle between *smoothed* and *non-smoothed*, highlight one polyline and press the right mouse button in the *3D View* to bring up the menu shown in Figure 14.6. Select or deselect *Smoothed* from the menu to toggle the status of the polyline.

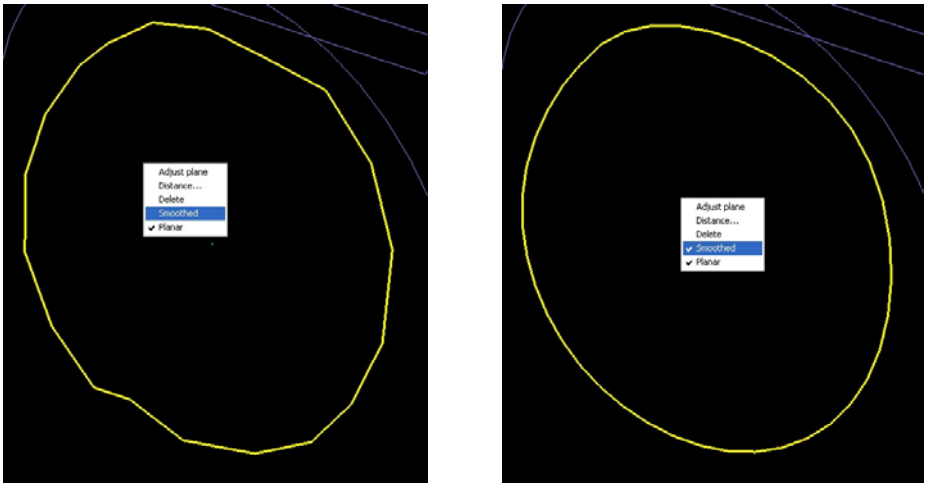
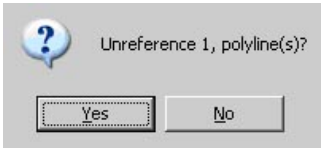


Figure 14.6

14.11 Referencing and Unreferencing Polylines

Sometimes the operator may not be satisfied with the calculated 3D polyline. In this case the entire 3D polyline object can be unreferenced in selected images and/or deleted altogether. Switch to *Select mode* (white arrow cursor) and highlight the polyline. Now use the right-click menu in the image where you want to unreference a single polyline. Select **Unreference** from the menu and press **OK** on the next dialog.



This will unreference the polyline in the current image. If the old 3D polyline was calculated from more than two polylines, the unreferenced polyline and the back projected polyline of the newly recalculated 3D polyline will be shown. If the old 3D polyline was calculated from only two polylines, it will now not exist in 3D (as at least two polyline measurements in 2D are required for the 3D calculation). It is also now possible to delete the unreferenced polyline.

If you forgot to highlight the referenced polyline to which your newly created polyline should refer, just select both polylines while you are in *PolyLine Marking Mode* and **Reference** them. *Australis* now calculates a new 3D object from all polylines related to both those selected.

14.12 Summary of Hotkeys/Short Cuts

BACKSPACE	undoes the last clicked point of polyline
ESC	cancels whole drawing process of current polyline
N	turns back projected polylines off
P	shows information about selected polyline

15. Texture Mapping to Generate Photo-Realistic 3D Models

15.1 Overview

The process of texture mapping involves the 'mapping' of image patches from selected *Australis* project images onto planar surface entities defined on the 3D object model displayed in the 3D View. An example of texture mapping is indicated below, where the 3D object photogram-metrically created from the seven images (Figure 15.1a) is textured to produce a photo-realistic representation (Figure 15.1b) that can be exported for subsequent viewing in VRML format.

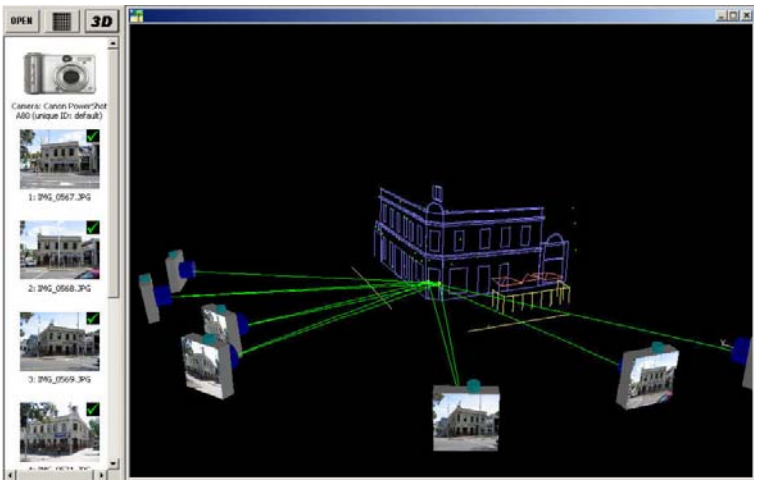


Figure 15.1a.

The process involved is image rectification, where the surface entities that are textured must be planar polygons (a triangle is the minimum), be visible from at least one oriented image and desirably have a convex boundary. If the planar condition is not fulfilled the texture will appear distorted to some extent. If the selected polygon is not convex, the texture can potentially be turned upside down, which would make it visible from the backside of the

entity, rather than the front. If no oriented image is available, or the entity is too large to fit into one orientated image a default texture (white) appears.

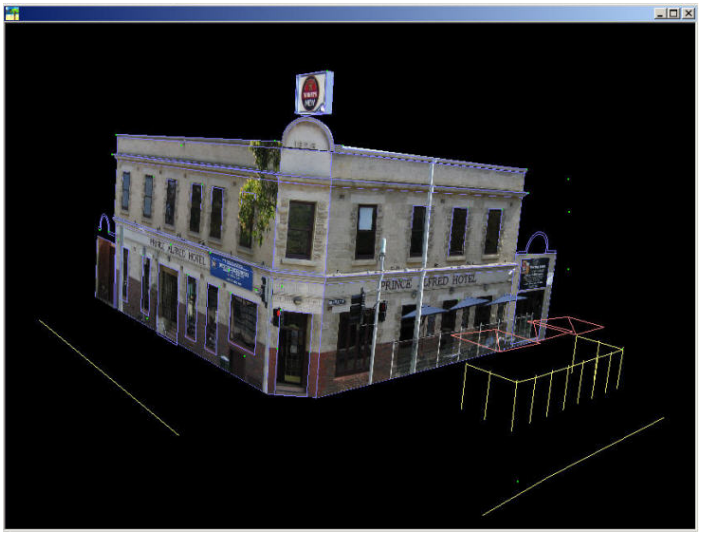


Figure 15.1b.

15.2 Selecting Texture Mapping Mode

The *3D Texture Mapping* mode is selected via the icon on the Toolbar. Upon selection of this mode, the cursor will change to one of the following symbols:

= ***3D Texture Mapping*** mode

= ***Point Construction*** mode

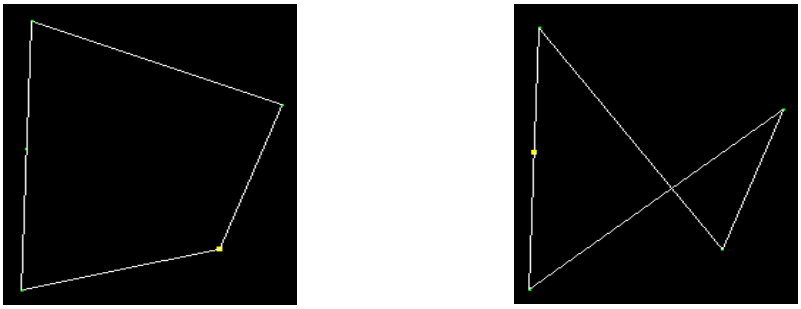
Textured entities can be created and modified in the *3D Texture Mapping* mode. In the *Point Construction* mode, additional 3D points can be created, to support the entity creation and to complete the visual 3D model by overlaying additional texture where necessary. To toggle between the two modes, the hot key **W** is used, as will be explained further in a following section.

15.3 Planar Surface Entity Creation

15.3.1 Point selection

To create an entity, at least three points or polylines that contains at least three points must be selected. Lines created via the *Australis* Line Tool are not considered. Upon point selection, a polygon appears that shows the boundary of the proposed entity. The selection can be carried out in either the *3D View* or *Image View* and the points have to be selected in a convex order, as indicated in Figure 15.2a. Figure 15.2b shows an invalid polygon selection. The entity boundary is drawn as the bounding points are selected.

Single points are selected via the left mouse button in the usual way. This can be done in either the *3D view* or in the *Image view*. Unlike all other point selection modes in *Australis*, predicted (blue) points can also be selected in the *Image View* when in texture mapping mode. The deselecting of the last selected point is possible by pressing the Backspace key.



(a) correct selection (b) invalid selection

Figure 15.2. Selected boundaries for entity creation

15.3.2 Selection of polyline points

Polylines can form boundaries of textured planar surface entities and they can be selected in the same way that single points are selected, again in either the *3D View* or *Image view*. A polyline is internally stored as a sequence of 3D points and it is possible to use only a subset of these in the texture mapping process. To 'shorten' a polyline from each end for texturing, use the **Backspace** and **CTRL + Backspace** to deselect points from both sides/ends of the polyline. To aid in this process, points of the polyline are highlighted and the start and end points are coloured green and red. For a closed polyline, at the beginning the start (green) and end (red) are the same and appear in red, as shown in Figure 15.3.

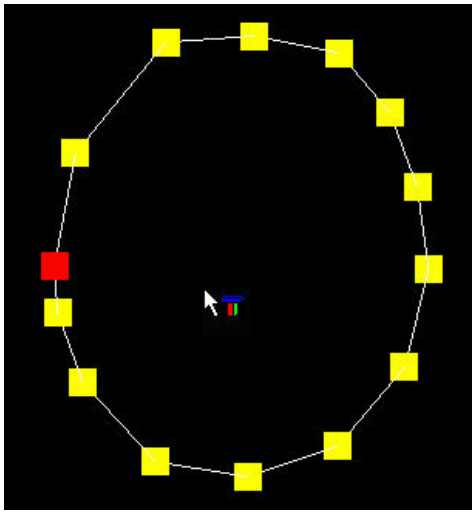
To deselect the red point use **Backspace** to deselecting the green point use **CTRL + Backspace**. Further selected points will be attached to the end point.

15.4 Texturing

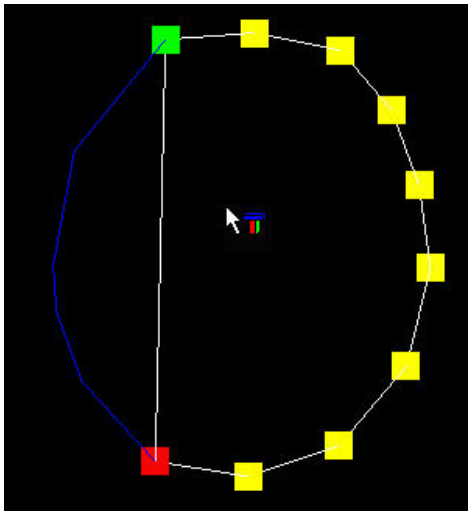
The texturing step follows immediately after the planar surface entity is generated. To texture a selected, bounded entity press the right mouse button in the *3D View*. The image patch to be rectified onto the surface entity will be automatically selected based on the geometry of the images forming the network. Normally, the best image is that whose orientation in 3D is most parallel to the entity surface. Only images from side of the viewing direction, from which the user is looking at the entity in the *3D View*, will be considered.

As an alternative to automatic texture selection, the user can specify a given image from which the texture will be taken. In this case, which occurs quite frequently because the automatic selection might not be the optimal choice because of occlusions or image quality, the user simply clicks the right mouse button within the desired *Image view*, or he/she selects (highlights) a chosen thumbnail within the thumbnail view and presses the **E** key.

The texture mapping of the entity will result in one of three outcomes, as shown in Figure 15.4. In the first, a texture will be mapped to the surface in the *3D View*. In the second, a yellow fill will appear, along with a message that there is no texture available (eg the selected entity is being viewed from the backside in the *3D View*). In the third, a default texture is assigned to indicate that the entity spans more than one image (ie entity is not contained within a single image).

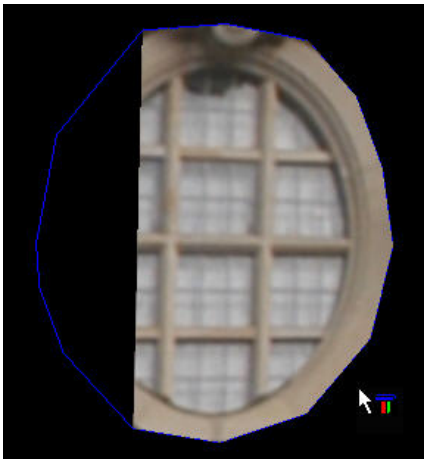


Selected points of a polyline



Polyline with four points excluded

Figure 15.3.



Textured entity

Warning message, if no texture is available; blank default texture

Figure 15.4.

Note: Textures can be toggled off and on via the **Z** key, and entities can also be created/textured when the visibility is toggled off.

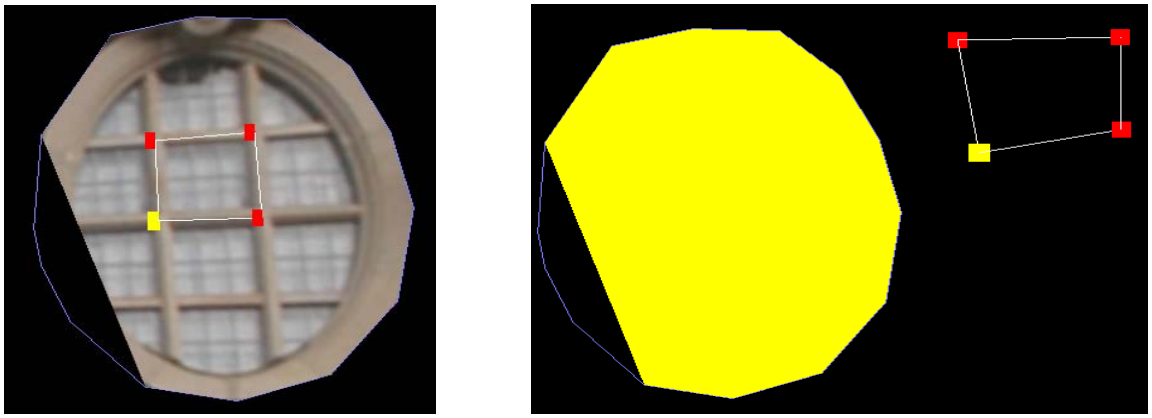
15.5 Generation of Constructed Points

3D *'Constructed Points'* can be created within the plane of an entity. The main purpose of these points is to enable the definition of additional sub-entities to allow further texturing within an existing textured entity. Constructed points appear in red in the *3D View*. *Point Construction* mode is invoked by pressing the **W** key.

There are two ways to generate a Constructed Point, as indicated in Figure 15.5:

a) Click on an existing entity in the *3D View*, or

b) Select an entity first (this represents a plane in 3D space) and click somewhere in the *3D View* or *ImageView*. The intersection point of this chosen image ray and the plane results into a constructed 3D point.



(a) Point construction within an entity (b) Point construction in relation to an entity

Figure 15.5. 3D point construction

Constructed Points are automatically selected for a later texturing. To complete the texturing, switch back to the texture mapping mode by pressing **W**, and click the right mouse button (in the *3D View* for automatic texture selection or in the *Image View* for manual selection).
The texturing of entities formed by Constructed Points is very useful for texturing over obstructions and occlusions, as indicated by the effective 'removal' of the pole from the texture mapped façade section shown in Figure 15.6.

Texture mapped pole to be removed

Pole is cut out; Constructed Points used to define an additional entity, which is textured

Figure 15.6.

15.6 Re-Texturing

In situations where it is required to change the texture within an entity, for example when the automatic image selection does not produce the optimal texturing or the default (white) texture needs to be replaced, the three re-texturing options are available:

15.6.1 Changing the image from which the texture is taken

Select the relevant entities, then:

a) choose an *Image View* and click the right mouse button, or
b) select a thumbnail of in the thumbnail window and press **E**, or
c) click the right mouse button in the *3D View*, and choose **Recalculate Texture** from the menu shown in Figure 15.7.

15.6.2 Assigning an artificial texture

It is possible to assign an artificial texture to a planar entity. This is often required when the default texture (no orientated image is available for texturing) appears. Select an entity and click the right mouse button and the *Entity menu* (Figure 15.7) appears. With **Set Texture**, an artificial texture (8bit, or 24bit TIFF, or JPG file) could be chosen. The texture will be stretched onto the chosen entity.

Through use of the Point Construction mode and artificial texturing, unrecorded areas of the 3D scene can be texture mapped in this way. This is a particularly useful way to fill small gaps between complex textured entities.

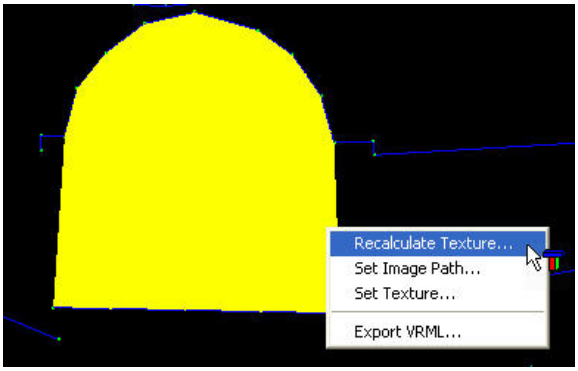


Figure 15.7. Menu resulting from right-click in a selected entity within the *3D View*.

15.6.3 Mapping the entity on its reverse side

It is possible to texture map an entity 'from behind', ie to have the texture visible from the opposite direction. To achieve this, first select the entity in the *3D View* and then rotate it into the position where the texture should be visible. Now, either:

a) choose an *Image View* and click the right mouse button, or
b) select a thumbnail of in the thumbnail window and press **E**, or
c) click the right mouse button in the *3D View*, and choose **Recalculate Texture** from the menu shown in Figure 15.7.

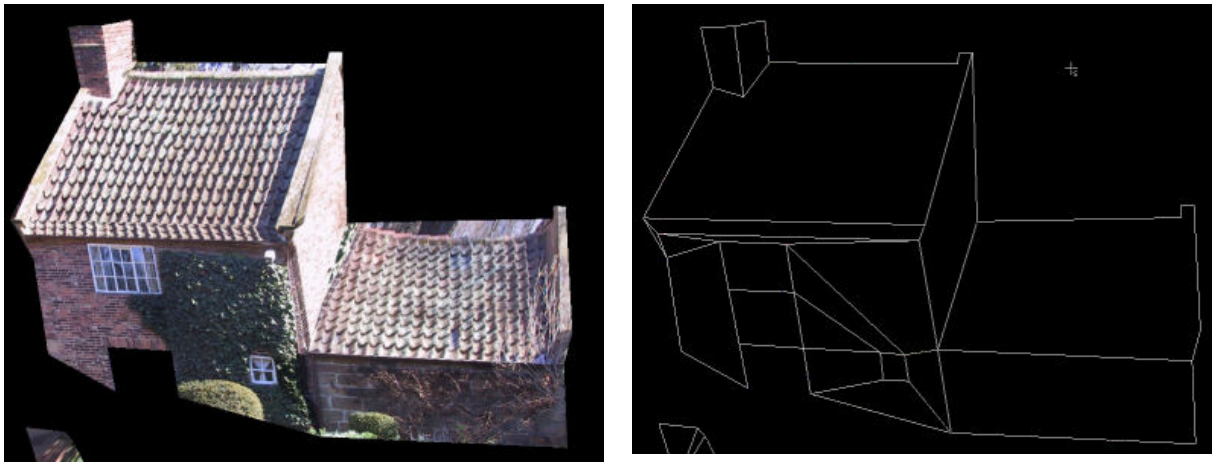
Note: To make the entity visible from both sides, a second entity must be created. See: "How to create an entity?"

15.7 Deleting Entities

To delete an entity or entities, select the entities and press the **Delete** key. Sometimes overlapping objects of the *OpenGL View* and *Image View* are simultaneously selected. You can choose individually which group of objects have to be deleted.

15.8 Export of Texture Mapped Object in VTML format

The virtual reality modelling language (VRML) is a well known 3D data format. The textured entities including the 3D vertices, image points of the texture and the texture itself can be exported using the *Entity menu* (Figure 15.7). A sample VRML view is shown in Figure 15.8. In addition to the VRML file, textures are saved as JPEG files. The image files comprise rectified images of the entities. A VRML Viewer is required to view the exported model.



VRML model Boundaries of entities

Figure 15.8. Views of the VRML model

Note: The textured entities will not be exported into DXF format, but the Constructed Points will be exported. Only geometric elements are stored in the exported DXF file from *Australis*.

15.9 Saving and Re-Loading the Project File

When the project is saved an additional subfolder for the entity textures is created in the current project folder. The subfolder contains the rectified entity images as tiff files.

If the project is moved to another folder, the image path of the entities has to be set in much the same way as occurs with normal *Australis* projects. In this case, to re-link the textures, select an entity, right click, and choose Select Image Path in the Entity Menu (Figure 15.7). The new image path can be assigned for all entities.

15.10 Summary of Hot-Keys

W	toggle point construction mode
Z	toggle entity visibility
D	toggle line visibility
E	for texturing with selected thumbnail of the project Bar

16. Adjustment of Image Scanning Parameters

16.1 Autoscanning

Within the autoscanning process, the aim is to detect ‘white blobs’ which are well contrasted against a dark background. Whether each of these blobs is a valid target or not depends upon a number of blob properties:

a) How ‘white’ it is compared to the background, ie is its greyvalue intensity sufficiently higher than the background?

b) Its size, ie is it too big or too small?

c) Its shape, ie is it elliptical and not long and thin?

Note in Figure 16.1 that there are four detected potential targets. The code is recognized, as is the valid target at the left of the figure, but the other two detected blobs are ‘hot spots’ from

the flash photography of the metal surface. These are not valid targets, but they have all the properties of targets.

The purpose of allowing the operator to adjust the scanning controls is to achieve settings that maximize the recognition of valid targets and minimize the detection of invalid targets. As seen in Figure 16.1, this is not always easy to achieve and it is very dependent on the imagery.

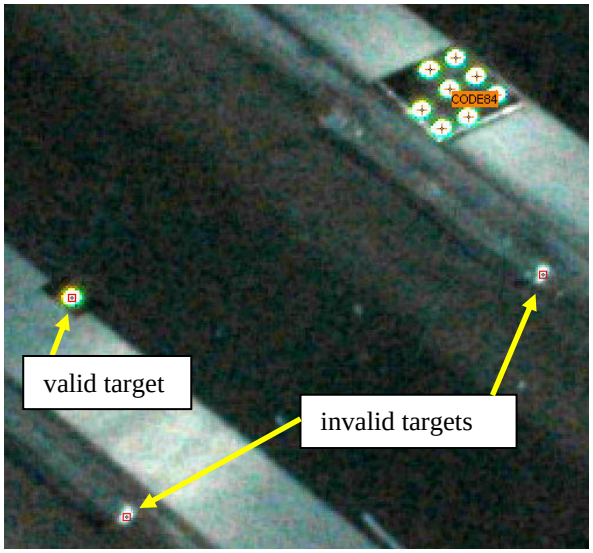


Figure 16.1

16.2 Autoscanning Control Dialog and Parameters

Figure 16.2 shows the *Image Scanning and Auto-Measurement* Settings dialog, which can be selected before or after the initial image scanning process (eg after **R++** or *imagescan only*). If selection is after an autoscan, the autoscanning must be run again with the new settings. After opening an image, the dialog is selected using either the **Q** key within the Image View or via the pull-down **Photogrammetry** menu selection **Image Scan Settings** (Image View window must be active). The window within the dialog shows the portion of the image where the user left-clicked (note the position of the cursor). Initially, this window is blank.

Of the two highlighted blobs (ie recognized as candidate targets) the one on the right is valid, whereas that on the left is invalid, but classified here by *Australis* as valid. Now consider each of the adjustment controls.

16.3 Target Scanning Parameters

1) **Threshold:** The threshold adjustment can be used to include only those target blobs whose intensity is sufficiently greater than the surrounding background. The threshold greyvalue step between background and a target will be larger for a highly reflective target. The default setting is 20 greyvalues (the maximum for an 8-bit image is 255) and a suitable setting for retrotargets against a moderately dark background is anywhere from 15 to 50.

Note what happens when the threshold in Figure 16.2 is changed to 36, as shown in Figure 16.3. Only the valid target remains and the ‘hotspot’ is not classified as a candidate target. Typically, sliding the threshold value to the right causes less blobs to be found, and more blobs (ie higher noise) are found when it is moved to the left.

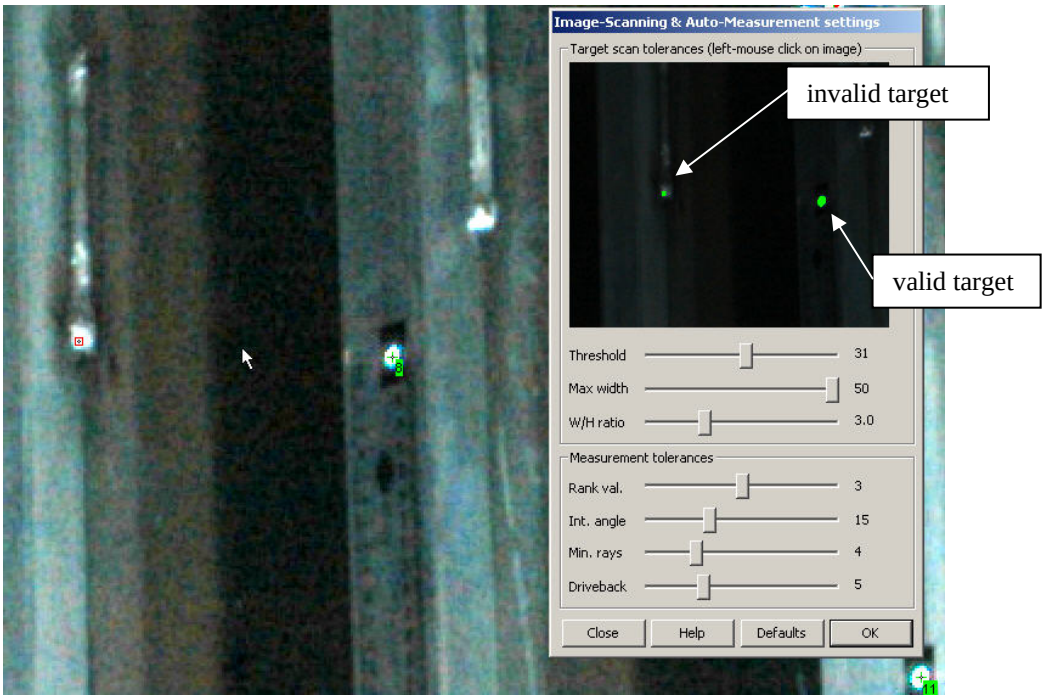


Figure 16.2

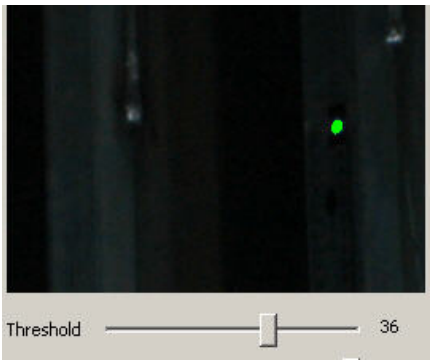


Figure 16.3

2) The **Maximum Width** (or diameter) simply specifies the largest size that a blob may have to be classed as a valid target. The default size is 50. There is no adjustable minimum size, that width being about 4 pixels. The ideal sizes for target blobs are from 5 to 30 pixels.

3) The **width-to-height** or **'W/H' ratio** is one measure of blob shape. A value of 1 would normally indicate a near-circular blob, which is generally what is required. A value of more than 4 (the default) would indicate a very thin, elongated blob, which is likely invalid.

16.4 Measurement Tolerance Parameters

The next four parameter values that can now be interactively changed relate to the point measurement process and specifically to the determination of matching unlabelled image points. These parameters are ***Rank Value***, ***Intersection Angle***, ***Minimum Number of Rays*** and ***Driveback Tolerance***. The function of these individual adjustments is as follows:

1) The **Rank Value** expresses the geometric tolerance applying to the ray-intersection geometry during the determination of corresponding non-coded targets in multiple images. There is a range of values from 1 to 5, with three being the default. Basically, the smaller the value, the larger the number of possible point matches (true targets and erroneous hot-spot targets). Thus, although more possible matches will be made, the automeasure process will slow down as this value is decreased towards 1. The admission of possibly many more erroneous point matches is not such a problem because these will usually be edited out in the final bundle adjustment. The ***recommended action*** here is to start with the default setting of 3. If valid target points are missed, then reduce the value to 2 and select **R++** and **CONTINUE** to re-run the Automeasure (it is not necessary to re-scan the images). Reduce the value to 1 if true target points are still missed.

2) The **Intersection Angle Limit** is an important tolerance to apply since it is often the case in networks with many images that erroneous targets arising from such factors as sun reflections are seen in closely adjacent images, which often means that they have very small angles of intersection. This is depicted in Figure 16.4, where the point out in the right side of the figure has a maximum intersection angle of 5 degrees. The *Intersection Angle Limit* can be used to omit such points.

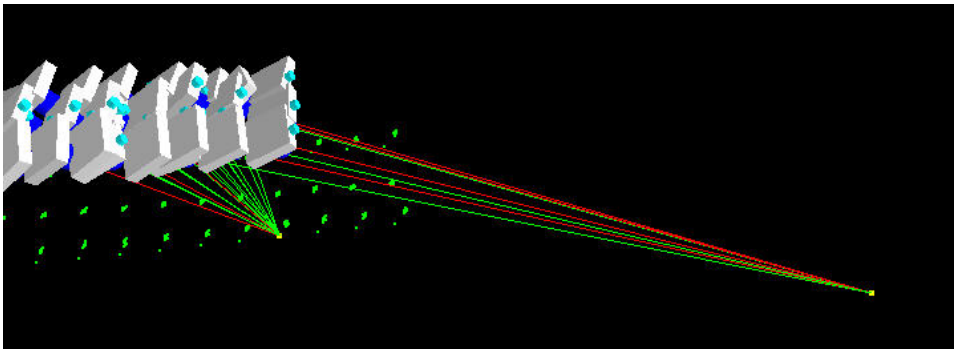


Figure 16.4

As a ***recommended action***, the default setting of 15 (degrees) should initially be used. To include points with a smaller intersection angle, move the slider to the left; the minimum admissible angle is 3 degrees. To omit more points, move the slider to the right, but note that this adjustment cannot be used to reject points with an intersection angle of more than 40 degrees. After adjustment, select **R++** and **CONTINUE** to re-run the Automeasure (it is not necessary to re-scan the images).

3) **Minimum Number of Rays.** This adjustment operates the same as the intersection angle condition, except that here points can be omitted in situations where they do not have a sufficient number of intersecting rays. The minimum number of rays for Automeasure is 2 and points with more than 10 rays cannot be omitted via this adjustment. The default number, which is recommended for strong multi-image networks is 5.

4) The **Driveback Tolerance** relates to the process that finds image points corresponding to 3D object points. Based on the image orientation, *Australis* looks within a certain location for a candidate image point matching a given object point. The *Driveback Tolerance* expresses the size of the window in which the search will be conducted for an image point. The tolerance value goes from 1 pixel to 15 pixels, with the default being 5 pixels. If it is found

that points are not being identified (labelled and triangulated), then relaxing the tolerance will increase the chance of finding more matching points. But, it will also increase the chance of finding close-by but wrong points. In general, this tolerance should rarely need to be adjusted.

16.5 Default Settings

Default values have been set for *Image Scanning* and *Automeasure Settings* and these can be reset at any time by selecting the **Defaults** button shown in Figure 16.2. The settings adopted via the dialog will only apply to the current project. Upon starting a new project, the settings return to the default values

16.6 Saving Autoscanning Settings

Selecting the **OK** button sets the assigned scanning values for all images within the project. Thus, some care must be taken in ensuring that the adjusted settings are most suitable for all images. Images can then be scanned or rescanned with the new settings.

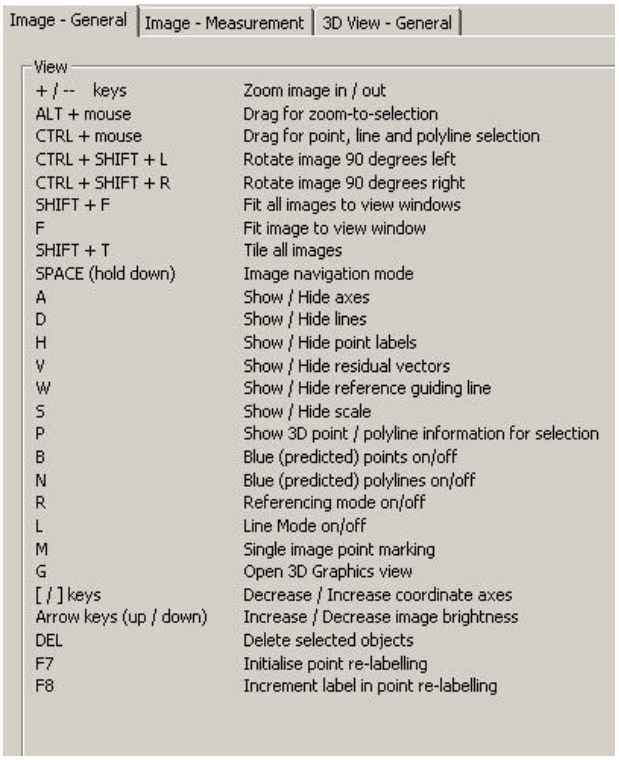
16.7 When to adjust the scanning settings

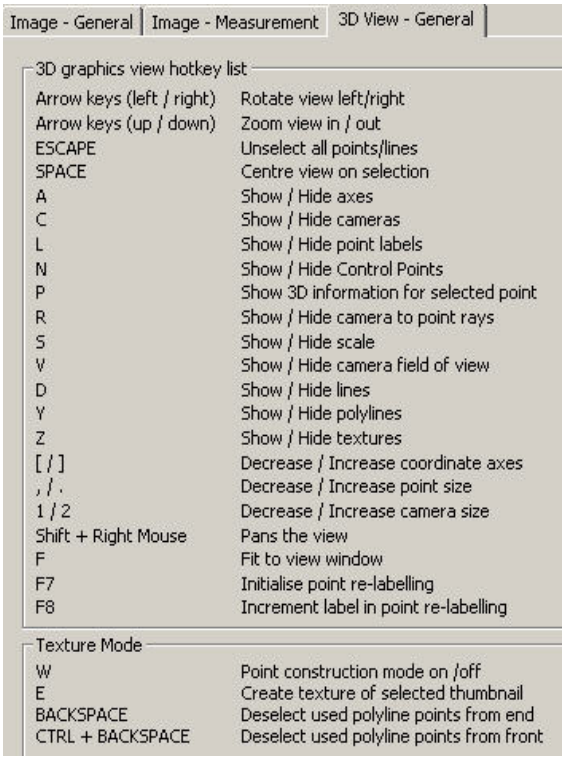
As mentioned, the *Q-selection* can be carried out before or after an Autoscan (eg **R++**), but if after, the autoscanning must be repeated with the new settings. The recommended time to adjust the target detection criteria is after the images are initially loaded into the project, before the first autoscan. Open a representative image, make the necessary adjustments and then run the autoscanning (via **Autocal** or **R++**).

APPENDIX A: Summary of Hotkey and Program Control Functions

A1. Index to *Australis* Hotkeys

The following hotkeys are utilised for operations within Australis. Note that this list is accessible via the **Help** menu & the '**?**' toolbar.





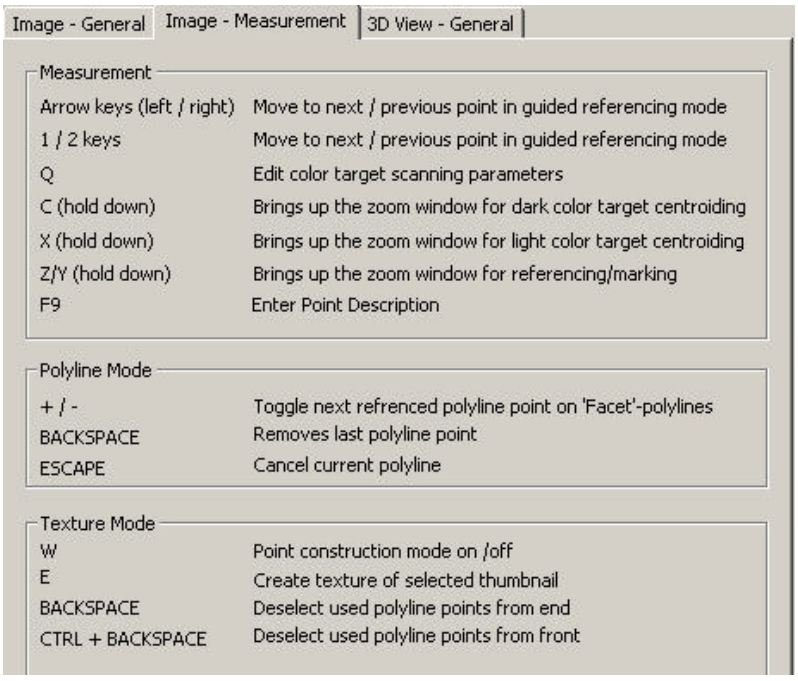


Image - General
Image - Measurement
3D View - General
Measurement
Arrow keys (left / right)
Move to next / previous point in guided referencing mode
1 / 2 keys
Move to next / previous point in guided referencing mode
Q
Edit color target scanning parameters
C (hold down)
Brings up the zoom window for dark color target centroiding
X (hold down)
Brings up the zoom window for light color target centroiding
Z/Y (hold down)
Brings up the zoom window for referencing/marking
F9
Enter Point Description
Polyline Mode
+ / -
Toggle next refrenced polyline point on 'Facet'-polylines
BACKSPACE
Removes last polyline point
ESCAPE
Cancel current polyline
Texture Mode
W
Point construction mode on /off
E
Create texture of selected thumbnail
BACKSPACE
Deselect used polyline points from end
CTRL + BACKSPACE
Deselect used polyline points from front

A2. Cursors and Toolbar Buttons

Further Cursors and Toolbar Buttons

Select Cursor: used for 'select' functions such as highlighting, dragging, etc.

Navigate Cursor: used for moving around within the image windows

Referencing Button: produces green 'pencil' used to mark corresponding pairs of feature points in the two images being 'referenced'. When two points are referenced, both are marked and identified as the same point in two images, seen from different viewing directions.

Auto-Referencing Button: Initiates fully automatic measurement via coded targets

Bundle Adjustment: Optional operator invoked processing of bundle adjustment

Line Cursor: used to build line segments between feature points (2 or more). These lines can be shown in both the graphics and image windows.

There are also two other cursors which are used, which do not have toolbar buttons:

Centroiding Cursor: used for auto-assisted marking (centroid measuring) of feature points; this requires suitable feature point targets. This cursor is activated - in referencing or marking mode only - by selecting either the **X** key (for white targets) or the **C** key (for dark targets).

Marking Cursor: red 'pencil' used to 'mark' image points to provide 2D image coordinates. This is accessed via the **M** keyboard key or pull-down menu **Photogrammetry|Single image point marking**. Marking is implicitly part of the referencing process and is thus not frequently required as a stand-alone procedure**.**

Also on the toolbar are the select buttons for the following functions:

Colour Button: for assigning colour to highlighted points and lines.

Review Button: Selects the Review or Edit mode, where the quality of each feature point determination can be verified

Status Summary: Provides a summary of the current status of the project

ScreenGrab: Provides a jpeg image file of the current screen contents

Step forward or backwards through the images when a single image is open in the image view

Buttons to **open a new** *Australis* project, **open an existing** project, and to **save the current** project.

In addition, there are also the '**?**' button and the selection buttons for **polylines** and **texturing**

A3. Rotating an Image

In order to rotate an image to make it view as 'upright', right-click in the image view and select **Rotate**. You will then have the option of rotating either +/- 90^o or 180^o. Once rotated, the image will stay in its new rotation throughout the project. The manual referencing function is easier when the two images being referenced are similarly oriented. The presence of camera rotations of +/- 90^o in the image network is quite important for camera self-calibration, so image rotation will be frequently encountered.

A4. Zooming within the image view

The four zoom options available in the active image window are:

i) The **Z** key. When the pencil cursor is over the point of interest, hold down the Z key to generate a zoom window. The cursor can then be accurately placed on the feature point of interest. The window will remain as long as the Z key is held down.

ii) The **ALT** zoom. Press the ALT key and use the mouse to draw a marquee box that will enclose the enlarged portion of the image.

iii) The '**+**' keyboard key to enlarge the image and the '**-**' key to reduce it.

iv) The mouse wheel (if present) can be used to zoom.

v) To 'zoom' the display size of labels, hold down the CTRL key and use the mouse wheel.

A5. Panning in the image view

To 'pan' or roam within an enlarged image, hold down the wheel of the mouse (or central button) and move the mouse. The slider bars can also be used for this function, as can dragging the mouse with left-button held down in Navigate mode.

A6. 3D View Functions (the cursor must be in the 3D View area)

i) To zoom in or out within the 3D view (make sure the cursor is over the 3D window), you can also use the roller ball on the mouse.

ii) To rotate the 3D View about the axis coming out of the screen, hold down the CRTL key and the right mouse button and move the mouse.

iii) To rotate the 3D View about the vertical axis on the screen, hold down the ALT key and the right mouse button and move the mouse.

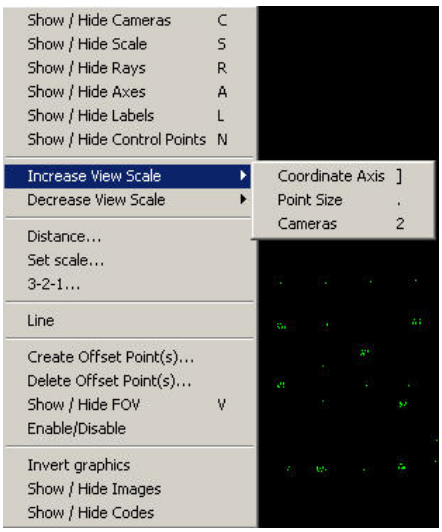
iv) To pan in the 3D View, use the SHIFT key and the right mouse button and move the mouse.

v) To bring a point to the centre of the 3D View display window, first highlight the point (left mouse button and drag) and then hit the Spacebar.

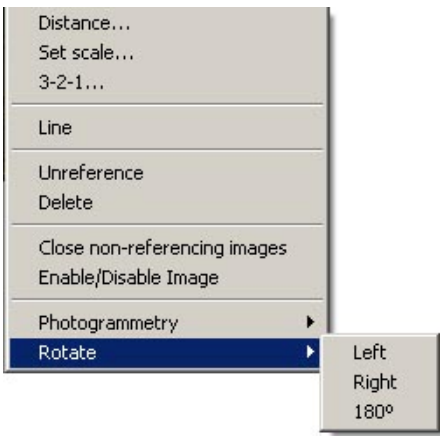
vi) Moving the mouse with the right button pressed and the point in (v) still highlighted will rotate the display about the highlighted point. Also the rotations described in (ii) and (iii) will be about the highlighted point.

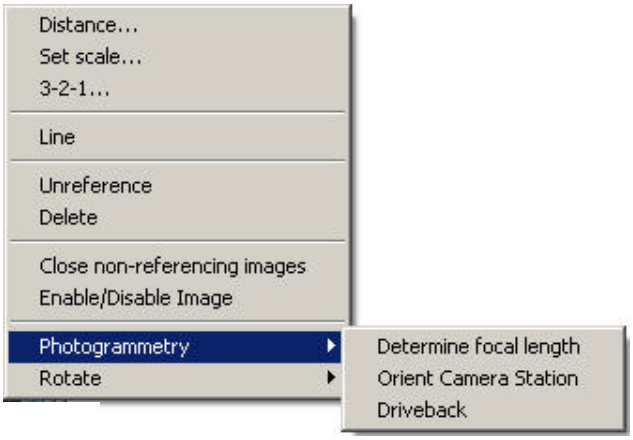
vii) To centre the network in the 3D View, use the F key.

A7. Menu from Right-Click in the 3D View (cursor must be in the 3D View area)



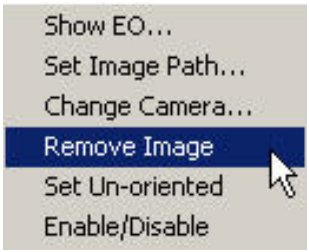
A8. Menu from Right-Click in the Image View (cursor must be in Image View)





A9. Deleting Images from the Project

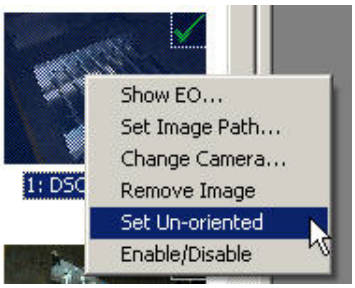
Right-clicking in the image thumbnails produces the following menu.



Select **Remove Image** to completely remove an image from the project

A10. De-activating a Referenced Image

If at any time it is desired to 'remove' a referenced image from the multi-image network, the operator need only right-click on the image thumbnail and select **Set Un-oriented**. The referenced points from that image are then effectively unreferenced. This operation should only be used with caution, for it may weaken network geometry. Also if a point on the 'un-oriented' image is only referenced to one other, then that point will be effectively removed from the 3D list.



A11. Re-orienting an Image

To reinstate a referenced image which has been 'removed' from the network by setting it un-oriented, simply open the image, right-click in Select Cursor (the white arrow) or Reference Mode and choose **Photogrammetry|Orient Camera Station|Orient**. A dialog box lists the status of the re-orientation.

A12. Re-orienting all Images

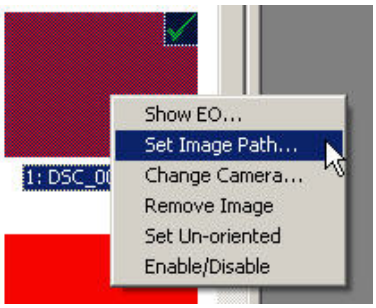
To re-orient all images at any given point in time, select **Orient all camera stations** from the **Photogrammetry** pull-down menu. Note, however, that it is very unlikely that you will need to use this facility in routine use of *Australis*.

A13. Relative Orientation

In the normal processing of *Australis*, all orientation functions occur automatically. In very rare instances the user may wish to explicitly orient one already referenced image to another. This process can be carried out by choosing **Relative Orientation** from the **Photogrammetry** pull-down menu. The two images for Relative Orientation are then chosen from the drop-down lists of images and **Compute** is selected. Following success of this process, the operator will be asked whether all other images should be re-oriented to this newly relatively oriented pair. The normal answer to this would be Yes, although it is always possible to re-orient all images at any time.

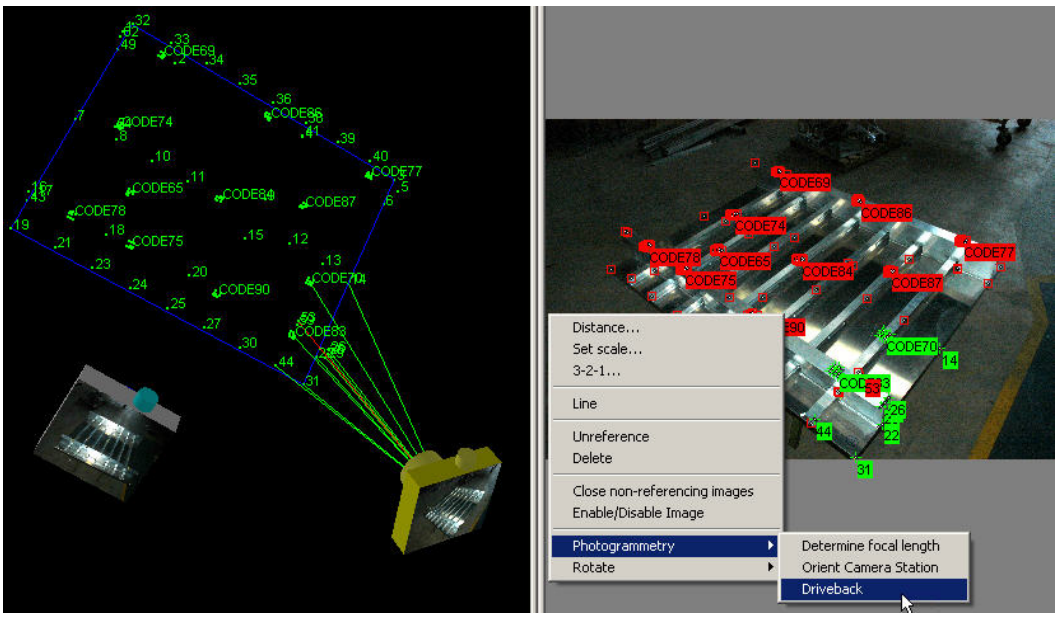
A14. Re-linking a Folder of Images to a Project

In the case where a project file (*projectname.aus*) is moved to another folder, along with its images, the images must be re-linked to the project if they are to be further used. You will know that this is the case because when you open the project by double clicking on the project file (*projectname.aus*), the image thumbnails will be red. To re-link, right-click on any thumbnail and choose **Set Image Path …** The directory holding the images then needs to be specified. After this, there will be a further option to **Set Path for All Images**, to which the answer is mostly *Yes*.



A15. Driveback

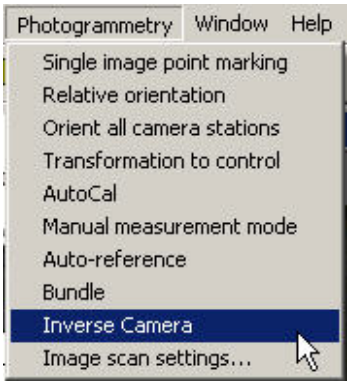
In instances where there is a network of oriented images and an object point array of 3D points, it is possible to automatically assign correct point labels to scanned points and measure there image coordinates. This process is called *Driveback*. To illustrate the concept, consider the situation depicted below, where there is a complete network, but one of the images has only some of the image points measured (but the rest are scanned). To automatically 'driveback' to and measure the unmeasured points, right-click in the Image View and select **Photogrammetry|Driveback**. This feature is useful for re-instating deleted or unreferenced points and also for repeat surveys where it is required to use the same point labels (automatic point re-labelling is an alternative approach).



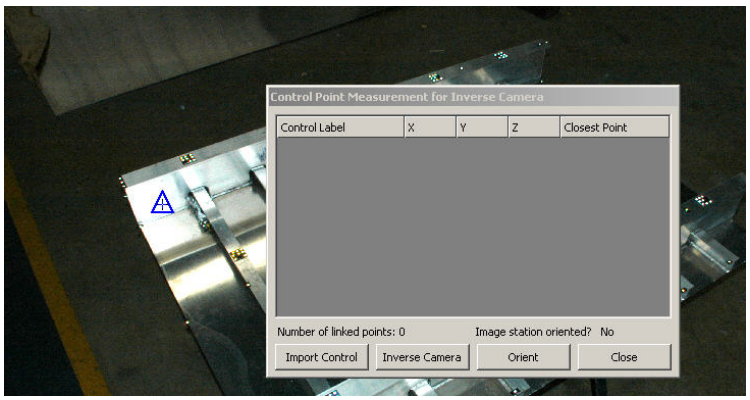
A16. Single Image Resection

Spatial resection, often termed *Inverse Camera* is the process by which the exterior orientation (EO) parameters (position and orientation) at an image station are determined from image coordinate measurements to four or more object space points with known XYZ coordinates. The function is most often employed to either gain approximate EO values for bundle adjustment, or to track a moving camera with respect to a fixed array of object points. The process to determine spatial resection in *Australis* proceeds as follows once the image(s) are loaded into the project:

1) Open the required image and select **Inverse Camera** from the **Photogrammetry** menu.



2) The control points measurement dialog for **Inverse Camera** will appear. Note also that the cursor will change to a blue triangle with a central cross.



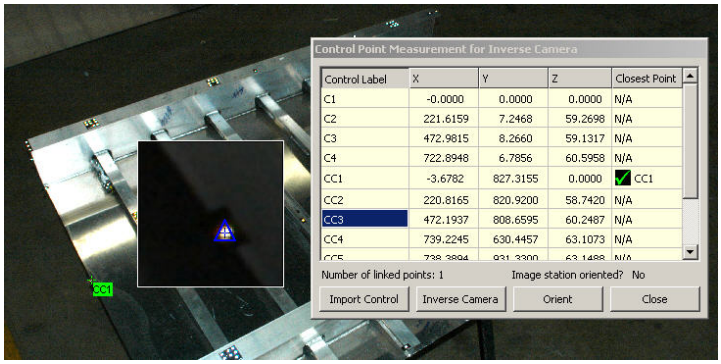
3) Select the **Import Control** button to load the desired text file of control points (structured as Label, X, Y, Z …). If a control points file has previously been loaded, it will be immediately displayed.

4) Then, either:

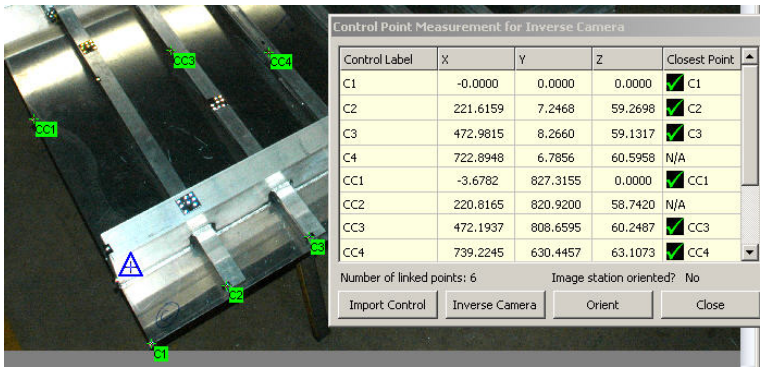
i) click on the desired control point label in the dialog box and then on the corresponding image point, or

ii) click on the image point followed by the label in the dialog box.

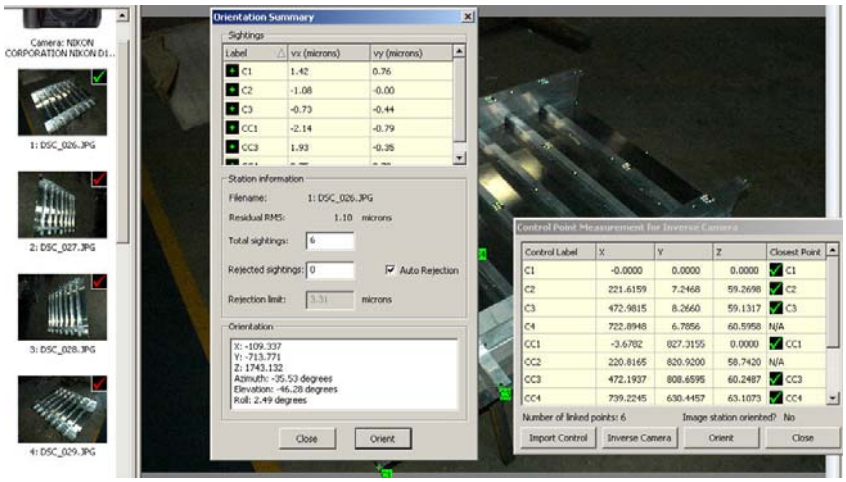
A green tick will appear once the image and control point have been linked. The figure below shows CC1 linked and CC3 selected in the dialog and about to be measured in the image



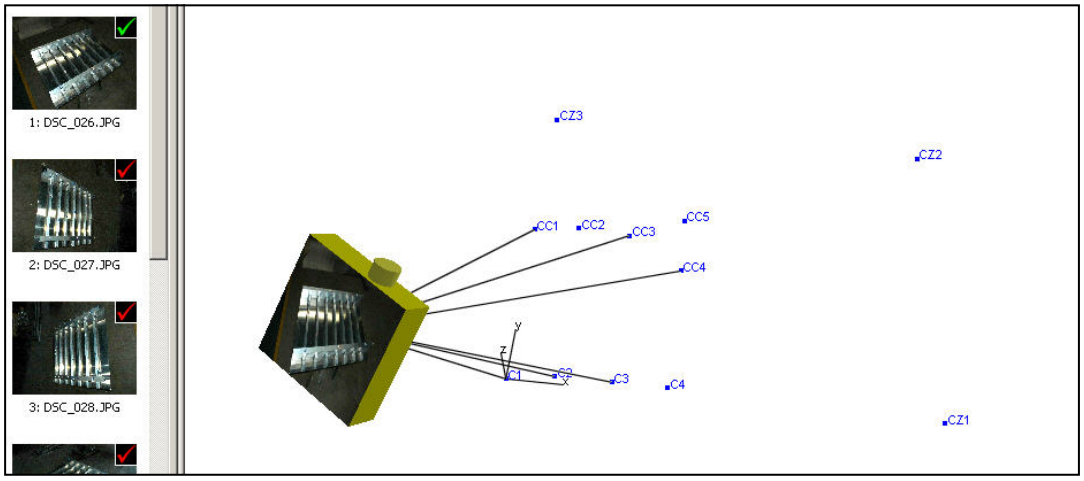
5) Link as many image and control points as desired, with 4 well-spread points being the minimum. The example below has 6 points linked (referenced)


Control Point Measurement for Inverse Camera
Control Label | X | Y | Z | Closest Point
C1 | -0.0000 | 0.0000 | 0.0000 | C1
C2 | 221.6159 | 7.2468 | 59.2698 | C2
C3 | 472.9815 | 8.2660 | 59.1317 | C3
C4 | 722.8948 | 6.7856 | 60.5958 | N/A
CC1 | -3.6782 | 827.3155 | 0.0000 | CC1
CC2 | 220.8165 | 820.9200 | 58.7420 | N/A
CC3 | 472.1937 | 808.6595 | 60.2487 | CC3
CC4 | 739.2245 | 630.4457 | 63.1073 | CC4
Number of linked points: 6
Image station oriented? No
Import Control
Inverse Camera
Orient
Close

6) When the desired number of points have been linked (4 or more), choose the **Orient** button. This will bring up the *Orientation Summary Dialog*, whereupon **Orient** is chosen from the dialog box. Orientation results are then displayed & the image thumbnail changes to green to indicate that the image is oriented.



7) The 3D View can be used to view the resulting position of the resected camera with respect to the control points used for the resection, as shown below.



A17. Entering a Point Description

A text description can be added for each object point, this being shown in the *3D List*:

Point Label	X	Y	Z	# Rays	Quality	Angle (deg)	Description
CODE90	-152.1416	5740.8055	-1569.5899	9	0.42	85.6	
1	476.3678	6244.8340	2094.7270	2	3.78	33.6	Cross Beam-A
2	4.6951	6705.7275	2005.0044	2	1.06	31.1	Cross Beam-B
3	-459.9176	7140.7890	1902.9748	2	1.83	28.8	End Point
5	-2559.7256	8570.0919	1052.4731	8	0.62	88.9	

Although this description can be added at any time via the *Point Dialog* (double-click on point label in *3D List* or highlight point in *Image* or *3D Views* and select the **P** key), it is often convenient to enter the description just before the point is initially referenced. To do this, either use the **F9** key or select **Point Description** from the **Edit** Menu. The following dialog box will appear:

The user need only enter the desired description and then choose OK. The description will then stay in effect until it is again changed.

A18. Exporting Orientation Parameters and Image Coordinates

Text files of the computed exterior and interior orientation parameters (EO/IO), as well as the image coordinates for each image, can be exported from *Australis* to the project directory by selecting the appropriate *Output Options* from the **Edit|Project Settings** dialog.

In the case of the EO/IO, the output text file name will be named *projectname_EOIO.txt*. Thus, there are two conditions necessary to generate this output file: first the project must have been saved and, second, a bundle adjustment must be run following the selection of the EO/IO parameters option.

The output image coordinate files are named *imagename.icf*.

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